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POLYURETHANE FOAMS FOR AIRCRAFT SHOCK MOUNTS. II. POLYBUTADIENE--ETC(U)
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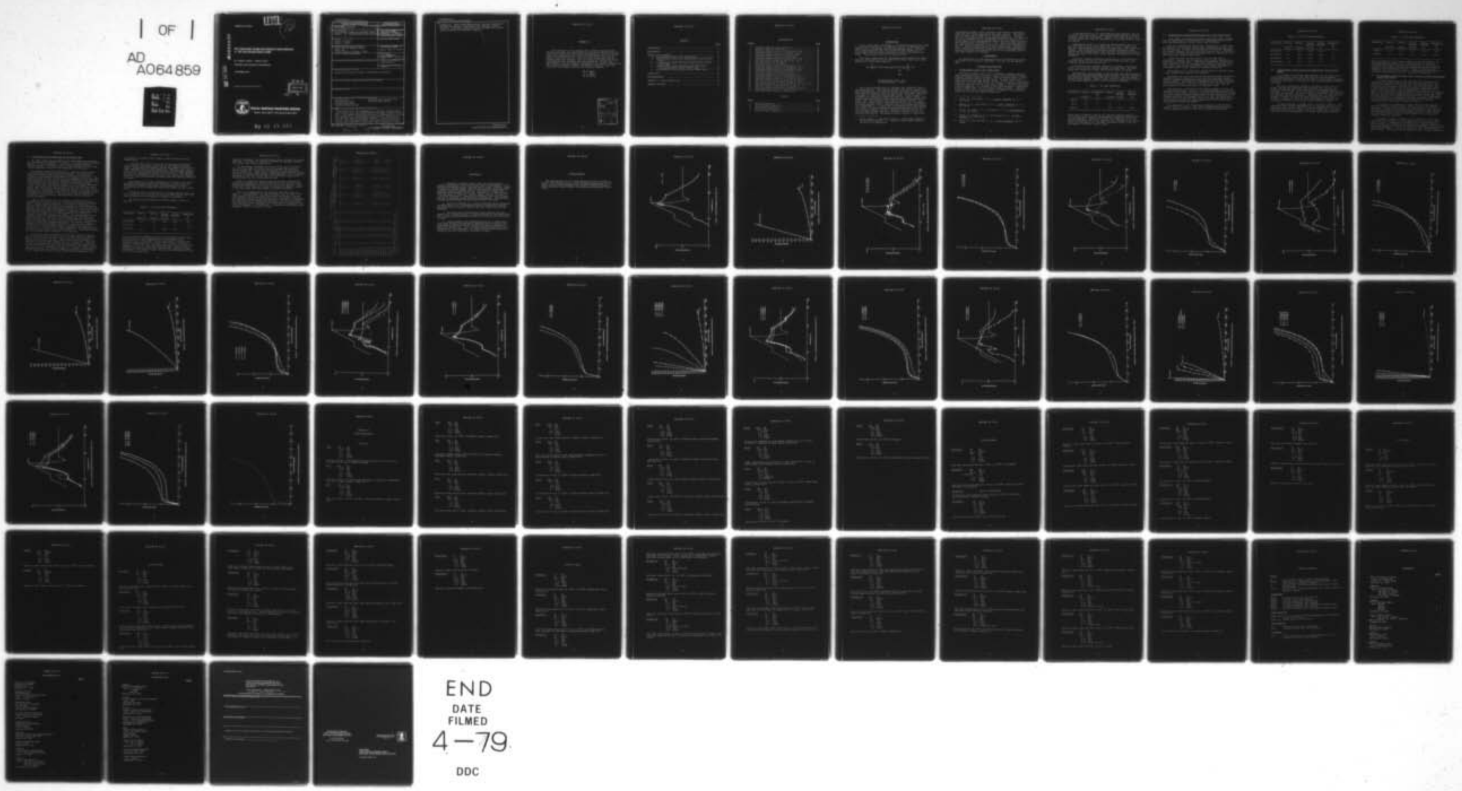

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POLYURETHANE FOAMS FOR AIRCRAFT SHOCK MOUNTS. II. POLYBUTADIENE BASED FOAMS

BY HUBERT J. BOOTH JAMES V. DUFFY

RESEARCH AND TECHNOLOGY DEPARTMENT

1 NOVEMBER 1978

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NSWC/WOL/TR-78-162	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) POLYURETHANE FOAMS FOR AIRCRAFT SHOCK MOUNTS. II. POLYBUTADIENE BASED FOAMS,		5. TYPE OF REPORT & PERIOD COVERED Progress Report October 1977-July 1978
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Hubert J. Booth, James V. Duffy		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Surface Weapons Center, White Oak, Silver Spring, Maryland 20910		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62241N; NIF; O; R31JA;
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 1 November 1978
		13. NUMBER OF PAGES 70
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

A061 482

(14) (6) (10) (9) (11) (12) 72p.

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Flexible Foam
Polyurethane Foam
Polybutadiene Foam
Vibration Damping Foam
Hydrolytically Stable Foam
Aircraft Shock Mounts

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of this program was to develop flexible foam systems which meet the specifications outlined in MIL-F-81334B (AS). This report deals with the results obtained from a series of foams based on polybutadiene polyol and its combinations with various types of polyether polyols. Polyol ratios, surfactant type and concentration, and catalyst type and concentration were evaluated to determine their influence on foam

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properties. Those foams demonstrating the most promise were measured for density, compression set, rebound, tensile strength, elongation, hydraulic fluid and hydrolytic resistance, porosity and vibration damping.

SUMMARY (U)

The objective of this program was to develop flexible foam systems which meet the specifications outlined in MIL-F-81334B (AS). This report deals with the results obtained from a series of foams based on polybutadiene polyol and its combinations with various types of polyether polyols. Polyol ratios, surfactant type and concentration, and catalyst type and concentration were evaluated to determine their influence on foam properties. Those foams demonstrating the most promise were measured for density, compression set, rebound, tensile strength, elongation, hydraulic fluid and hydrolytic resistance, porosity and vibration damping.

J. R. Dixon

J. R. DIXON
By direction

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INTRODUCTION

In our first report (Reference 1) on flexible polyurethane foams for aircraft shock mounts, we detailed some of the chemistry and physics used in preparing flexible polyurethane foams. Additionally, some background into the problem of foam degradation in shock mounts and our general approach to solving the problem was given. These factors will not be repeated here.

This report deals with the development and evaluation of foams based on polybutadiene polyol (general structure below) and combinations of it with other polyols.

$$HO-\left[\left(CH_2-CH=CH-CH_2\right)_{0.8}-\left(CH_2-\underset{\begin{array}{c}|\\ CH\\ \|\\ CH_2\end{array}}{CH}\right)_{0.2}\right]_X-OH$$

POLYBUTADIENE POLYOL (HT)
OH functionality ≈ 2.4-2.6

The polyols combined with HT included four different types of polyether polyols. One type was Pluracol 718 (PL718), based on a poly(oxypropylene) triol containing only secondary hydroxyl groups. This type of polyether polyol is widely used to prepare commercial "one-step" or "one-shot" polyurethane foams. PL718 is easily processed and generally yields high open cell content foams. The second class of polyether polyol used was poly(oxytetramethylene) glycol (PM) which contains only primary hydroxyl groups. This glycol has, within limits, good miscibility with HT. Elastomers and foams prepared from it generally have good mechanical properties (Reference 1). A third type of polyether polyol was Pluracol 355 (PL355), an amine containing poly(oxypropylene) tetrol which has secondary hydroxyl groups. Because of the presence of the tertiary amine groups with their catalytic behavior, PL355 is a very reactive polyol. Furthermore, being a tetrol of relatively

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1. Booth, Hubert J., and Duffy, James V., Polyurethane Foams for Aircraft Shock Mounts. I. Polyether Based Foams, NSWC/WOL TR 78-125, in publication.

low molecular weight, PL355 introduces considerable crosslinking sites per unit volume compared to the other polyols. The fourth type of polyol was a class called "polymer polyols". "Polymer polyols" are prepared from the in situ polymerization (or grafting) of a vinyl monomer such as acrylonitrile onto the backbone of a polyol based on poly(oxypropylene) and/or ethylene oxide terminated poly(oxypropylene) (References 2, 3, 4). These "polymer polyols" are used in the manufacture of high resiliency foams (References 5 and 6). Added to high resiliency foam formulations, "polymer polyols" improve the mechanical properties such as increased modulus, fatigue resistance, and durability and act as processing aids in that they improve cell opening.

EXPERIMENTAL

An explanation of foam preparation and test methods and procedures was fully covered in Reference 1 and will not be repeated here.

RESULTS AND DISCUSSION

I. Polybutadiene Polyol (HT) Based Foams

The first attempts (HT-1 to 4) to prepare a flexible polyurethane foam based on HT as the sole polyol failed because of either internal fissures and/or collapse. The tin catalyst used in these formulations was stannous octoate (T-9); the tops tended to be tacky, and the cells were mostly closed. In HT-5 and 6, dibutyltin dilaurate (T-12) was used as the tin catalyst. The result was faster cream time and set with no tacky tops. However, failure occurred by internal fissuring. An increase in the amine catalyst, triethylenediamine (DABCO 33LV), did not prevent fissuring (HT-6). The best HT foam to date (HT-7) was obtained by increasing the surfactant, DC198, but it was still mostly closed cell.

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2. Patten, W., and Priest, D. C., J. Cell. Plastics, 8, (3), 134 (1972).

3. Robson, J. H., and Priest, D. C., J. Cell. Plastics, 9, (1), 119 (1973).

4. Patten, W., Rose, C. V., and Benson, A. J., J. Cell.Plastics, 9, (2), 92 (1973).

5. Patten, W., Seefried, C. G., and Whitman, R. D., J. Cell. Plastics, 10, 276 (1974).

6. Patten, W., and Seefried, C. G., J. Cell. Plastics, 12, 41 (1976).

In the series HT-8 to 15, the DC198 was held constant, and the T-12/33LV ratio was varied. These foams failed because of either internal fissuring or shrinkage. However, HT-10 was the best foam in this series, and from its formulation a T-12/33LV ratio of 0.2/0.5 was chosen.

Formulations HT-16 to 19 varied the DC198 content from 1 to 5 phr while the T-12/33LV ratio was held at 0.2/0.5. While there were no fissures above 2 phr DC198, the foams had a high closed cell content. The formulations containing higher surfactant levels (HT-18 and 19) creamed faster than the other formulations possibly because the higher surfactant level improved the miscibility of the components.

HT-20 was a double formulation containing 2.5 phr DC198 and a T-12/33LV ratio of 0.2/0.5. The resulting foam had small side fissures and was mostly closed cell.

A different amine catalyst (HT-21) or different surfactants (HT-22 to 25) did not yield a suitable HT based foam. The foams which were closed cell either had fissures and/or collapsed.

Qualitatively, the strength of the HT foams was poor and would not have met the MIL-F81334B(AS) specification. Not many properties were measured because these foams (HT-1 to HT-25) did not warrant further investigation. Table 1 lists those few properties measured. The vibration damping curve of HT-20 is given in Figure 1.

TABLE 1 - HT FOAM PROPERTIES

Formulation	Density (lbs/ft^3)	Compression Set (%)	Rebound (inches)	Energy Absorbed (Joules)	Energy Absorbed (%)
HT-10	3.2	--	--	--	--
HT-17	3.5	--	--	--	--
HT-20	3.7	4	14.5	0.677	55.8

Given also in Figure 1 (and in all vibration damping figures) is the envelope curve defining the maximum allowable acceleration at a given frequency. [See MIL-F-81334B (AS) (Reference 1).] The damping properties for the HT foams are poor between 40 and 150 Hz. Thus, the development of a suitable foam based solely on HT did not appear to be worth further effort.

II. Polybutadiene Polyol/Poly(oxypropylene) Polyol Based Foams

In an effort to obtain more stable, open cell foams, development of foams based on combinations of polybutadiene polyol (HT) with poly(oxypropylene) polyol (PL718) was initiated.

The first formulation (HT-PL718-1) consisted of a 70/30 ratio of HT/PL718. The foam was stable, had a good cream and set, and did not fissure. A double mix formulation (HT-PL718-2) contained no internal fissures, but the cells were coarser than in HT-PL718-1. The use of a stirrer in HT-PL718-3 gave finer cell structure, but some small side fissures were noted.

A HT/PL718 ratio of 50/50 with a T-9 cure was used in HT-PL718-4. However, the mix was not "hot" enough, resulting in poor rise and a thick skin. Subsequent formulations of the 50/50 ratio (HT-PL718-5 to 15) involving T-12 catalyst, different T-12/33LV ratios, and varying surfactant levels proved unsuccessful. The foams usually failed because of internal fissuring.

Investigation of a 30/70 ratio (HT-PL718-16) of HT/PL718 gave a fine, closed cell foam with no fissures.

Generally, the cell structure of the HT-PL718 foams was characterized by having a majority of the cell wall membranes intact. However, enough of the membranes had small center holes to prevent foam shrinkage. The foams, as evidenced by the gas flow curve for HT-PL718-1 in Figure 2, cannot be classified as truly open cell when compared to PL-4, and open cell polyether foam.

Qualitatively, the HT-PL718 foams would probably not meet the strength requirements. However, the vibration damping curves for HT-PL718-2 and 3 shown in Figure 3 indicate that the HT-PL718 foams have good vibration damping properties, falling slightly out of the standard envelope curve between 50-100 Hz. The load deflection curves (Figure 4) for HT-PL718-2 and 3 indicate that their initial load bearing strengths are approximately 0.3 $lb/in.^2$ less than required by the MIL-F-81334B(AS).

The remainder of the limited data obtained on some HT-PL718 foams is given in Table 2. The percent compression set measured for the samples was well within the 10% maximum requirement.

TABLE 2 - HT-PL718 FOAM PROPERTIES

Formulation	Density (lbs/ft^3)	Rebound (inches)	Energy Absorbed (Joules)	Energy Absorbed (%)	Compression Set (%)
HT-PL718-1	3.0	11.5	0.86	70.8	--
HT-PL718-2	2.7	11.8	0.84	69.4	2.2
HT-PL718-3	2.7	10.5	0.91	75.4	3.8
HT-PL718-16	3.0	10.0	0.94	77.7	--

III. Polybutadiene Polyol/Poly(oxytetramethylene) Glycol Based Foams

In an effort to introduce some strength into HT foams, poly-(oxytetramethylene) glycol (PM) was added to the formulations. Previously (Reference 1) when PM was added to polyurethane elastomer or foam formulations, the strength of the resulting material usually increased.

The first formulation (HT-PM-1) utilized a 70/30 ratio of HT/PM. The mixture exhibited good cream and set; however, the resulting foam had small side fissures and incomplete membrane pullback to cell ribs. To rid the foam of the fissures and increase the open cell content, the next formulation (HT-PM-2) contained less T-9 catalyst and more surfactant. Unfortunately, the foam had an internal fissure, but there was more membrane pullback than in HT-PM-1. A switch in ratio to 30/70 and changes in catalyst and surfactant (HT-PM-3 to 5) did not yield an open cell foam.

The data obtained on HT-PM-3 and 5 is given in Table 3. The relatively high percent compression set is probably because of the high percentage (70%) of PM used in these formulations. PM is a difunctional polyol and, hence, lowers the number of crosslinking sites per unit volume compared to a higher functionality polyol.

TABLE 3 - HT-PM FOAM PROPERTIES

Formulation	Density (lbs/ft^3)	Rebound (inches)	Energy Absorbed (Joules)	Energy Absorbed (%)	Compression Set (%)
HT-PM-3	3.6	12.7	0.79	65.2	6.8
HT-PM-5	4.2	16.0	0.57	47.1	10.8

Even though HT-PM-5 has a higher rebound value than HT-PM-3, the vibration damping properties of HT-PM-5 are better (Figure 5). This observation points out again (see Reference 1) that there is no simple relationship between ball rebound and dynamic vibration damping in the frequency of concern. Figure 6 gives the load deflection curves for HT-PM-3 and 5. Formulation HT-PM-3 had satisfactory load deflection values. [See MIL-F-81334B(AS).]

IV. Polybutadiene Polyol/Tertiary Amine Containing Poly(oxypropylene) Polyol Based Foams

A general observation of the foams based on HT alone and in combination with the other polyols was that the reactivity (as measured by cream time, rise time, set, and tack-free time) was lower than one would have expected for a polyol containing mostly primary hydroxyl groups. One of the possible reasons for this lower reactivity of HT is the incompatibility of the HT with the water. The commercial polyether polyols (including PM) are generally miscible with the water needed to blow the foam; HT was not. Heat from the reaction is not generated as rapidly in the nonhomogenous HT formulations as in homogenous mixtures. Therefore, poor rise, as well as difficulty in matching the blowing and gelation (polymerization) reactions, can and did result.

In an effort to increase the reactivity of HT formulations, a tertiary amine poly(oxypropylene) tetrol, Pluracol 355 (PL355), was added. Tertiary amine groups are known catalysts for both the isocyanate-hydroxyl and isocyanate-water reactions. Additionally, the high functionality and low molecular weight of PL355 result in increased reaction sites per unit volume. Thus, the heat of reaction should be increased.

HT-PL355-1, based on a 90/10 ratio of HT/PL355, gave a foam rise which was the best of any HT based foam, but the cells were mostly closed. A double mix (HT-PL355-2) with reduced catalyst gave a coarse cell foam while decreased amine catalyst (33LV) and increased surfactant (HT-PL355-3) yielded a foam with quite different cells than HT-PL355-1. The cells were finer and less coarse but still closed. The reactivity was deemed to high. Further decreases

V. Polybutadiene Polyol/Polymer Polyol Based Foams

The most stable and reproducible HT based foams were prepared by the addition of Pluracol 637 (PL637), a "polymer polyol" (grafted polyol), to the formulation. This polyol contains secondary hydroxyl groups. A HT/PL637 ratio of 70/30 was used in all formulations except HT-PL637-29 which contained a 50/50 ratio.

The initial formulation (HT-PL637-1) utilized T-12 and DABCO 33LV as cocatalysts with DC198 as surfactant. A stable foam resulted but had a high percentage of closed cells (Figure 10). HT-PL637-1 had borderline load deflection values (Figure 11). The vibration damping curve (Figure 12) was comparable to the presently used material. A reduction in surfactant (HT-PL637-2) did not seem to noticeably affect the foam's vibration damping performance (Figure 12) or load deflection (Figure 11). An attempt (HT-PL637-3) to get a more open cell foam by lowering the T-12 catalyst gave a stable foam but one that cured poorly on top and still was mostly closed cell. The effect of low catalyst content can be seen in the different load deflection (Figure 11) and vibration damping (Figure 12) behavior of HT-Pl637-3. The foam had a soft feel which was reflected in the low initial load deflection values and high vibration damping.

A switch (HT-PL637-4) to T-9 catalyst, a less reactive tin catalyst, to get a more open cell foam proved largely unsuccessful. While a stable foam was prepared, it was mostly closed cell, and the top became tack free only after overnight at room temperature. However, the T-9 cured formulation (HT-PL637-4) yielded a foam that had good vibration damping properties (Figure 12) and better initial load bearing properties than HT-PL637-3 which was cured with a low T-12 content (Figure 11). A lower amount of T-9 (HT-PL637-5) yielded a foam that fissured and shrank. Increased amounts of T-9 (HT-PL637-6 and 7) gave better curing foams, but they were still mostly closed cell. However, the T-9 cured foams were generally more open cell than the T-12 cured foams (Figure 15). Additionally, Figure 13 shows that increased amounts of T-9 (HT-PL637-6 and 7) degrade the vibration damping properties (compare with HT-PL637-4 in Figure 12). On the other hand, the load bearing properties (Figure 14) of HT-PL637-6 and 7 were acceptable. We concluded that T-9 was not a sufficiently hot enough catalyst in reasonable amounts to cure HT based foams; therefore, T-12 was used.

A series of foams (HT-PL637-8 and 10) where the T-12 content was varied while the surfactant level was held constant indicated that a level between 0.10 and 0.20 phr of T-12 was required to obtain a good, tack free cure. These foams were more closed cell than the T-9 cured foams (HT-PL637-6 and 7, Figure 15). Contrary to what was expected, the formulation containing the highest T-12 level (HT-PL637-10) was more open cell than the foam cured with the low level of T-12 (HT-PL637-8, Figure 15). Figure 16 shows little difference between the vibration damping properties of HT-PL637-8 to 10. There was a general trend towards poorer damping as the

in catalyst (HT-PL355-4 and 5) gave a foam with good rise but closed cells.

A switch from T-12 to T-9 as the tin catalyst (HT-PL355-6 to 8) gave very soft foams unlike any of the previous HT-PL355 foams. Proper cure was suspect, and the top became tack-free only after overnight cure at room temperature. However, those foams cured with T-9 had significantly more cell wall membrane pullback to the cell ribs than those foams cured with T-12. This observation was not unexpected since T-9 is a less reactive tin catalyst than T-12, and T-9 allows more pullback since the gelation reaction is slower.

The density of the above foams was too low with 2 phr water; therefore, the water content was reduced to 1.5 phr. Resulting formulations prepared with either T-9 (HT-PL355-9) or T-12 (HT-PL355-10 to 12) yielded poor foams that shrank and had closed cells.

A HT/PL355 ratio of 70/30 with T-9 catalyst (HT-PL355-13) was used as well as a 97/3 ratio with T-9 cure (HT-PL355-14) and T-12 cure (HT-PL355-15) with resultant collapse or shrinkage.

The limited data collected on HT-PL355 foams is given in Table 4.

TABLE 4 - HT-PL355 FOAM PROPERTIES

Formulation	Density (lbs/ft^3)	Rebound (inches)	Energy Absorbed (Joules)	Energy Absorbed (%)	Compression Set (%)
HT-PL355-1	2.5	12	0.83	68.5	20
HT-PL355-2	--	--	--	--	17.6
HT-PL355-4	2.5	9.7	0.96	79.0	--

While the vibration damping properties of HT-PL355-1 looked promising (Figure 7), the compression set was extremely poor. HT-PL355-1 and 2 also exhibited poor resistance to initial compression loading (Figure 8). The gas flow curve of HT-PL355-8 (Figure 9) shows that this foam has a high content of closed cells compared to PL-4, an open cell polyether foam. Based on these observations along with the poor qualitatively assessed strength properties of the HT-PL355 foams, further work incorporating PL355 with HT was discontinued.

catalyst increased. The load deflection curves (Figure 17) clearly show that a low level of catalyst (HT-PL637-8) adversely affects the initial load bearing properties.

One formulation (HT-PL637-29) used a 50/50 ratio of HT/PL637. The resulting foam was stable, had no fissures, but was still mostly closed cell. Other than increasing the load deflection values (Figure 25), which was not unexpected since "polymer polyols" are used to increase foam modulus, there appeared to be no obvious advantage in the 50/50 ratio over the 70/30 ratio; thus, 50/50 formulations were not investigated further.

While the foams have been classified as mostly closed cell, microscopic examination revealed that some of the cell wall membranes had pullbacked to the cell ribs to varying degrees. Since the HT-PL637 foams generally showed no tendency to shrink, enough of the cells must have been opened to prevent shrinkage.

Some of the properties of the HT-PL637 foams are given in Table 5. The compression set was acceptable (10% or less) in all foams except HT-PL637-8. This foam, however, had only 0.05 phr T-12 catalyst and was probably undercured. The tensile strength and elongation values do not meet the specifications. As proposed, the foams excelled in hydrolytic stability. The HT-PL637 foams, like polyether foams, exhibited poor resistance to hydraulic fluid with approximately a 50% reduction in strength and elongation upon exposure (1 hour) to hydraulic fluid.

TABLE 5 - HT-PL637 FOAM PROPERTIES

Formulation	Density (lbs/ft^3)	Rebound (inches)	Energy Absorbed (Joules)	Energy Absorbed (%)	Compression Set (%)	Tensile Strength (psi)** Untreated	Tensile Strength (psi)** Hydrolytic* Ageing	Tensile Strength (psi)** Hydraulic Fluid	Elongation (%)** Untreated	Elongation (%)** Hydrolytic* Ageing	Elongation (%)** Hydraulic Fluid
HT-PL637-1	2.7	11.0	0.884	73.1	6.5	11.8	11.9(+1)	6.1(-48)	108	99(-8)	62(-43)
HT-PL637-2	2.9	10.6	0.908	75.0	9.8	—	—	—	—	—	—
HT-PL637-3	2.9	10.6	0.908	75.0	8.3	—	—	—	—	—	—
HT-PL637-4	2.8	10.4	0.920	76.0	3.2	—	—	—	—	—	—
HT-PL637-6	3.2	11.3	0.872	72.1	4.0	—	—	—	—	—	—
HT-PL637-7	3.0	11.3	0.872	72.1	3.9	14.7	14.0(-5)	—	113	106(-6)	—
HT-PL637-8	2.7	10.0	0.94	77.7	18.3	11.6	11.6(0)	5.4(-53)	103	100(-3)	52(-50)
HT-PL637-9	2.7	10.8	0.892	73.7	6.2	11.2	10.4(-7)	5.8(-48)	101	99(-2)	60(-41)
HT-PL637-10	2.7	11.0	0.884	73.1	8.6	12.2	12.2(0)	6.8(-44)	115	118(+3)	68(-41)
HT-PL637-11	3.5	11.7	0.844	69.8	4.3	—	—	—	—	—	—
HT-PL637-13	2.9	10.0	0.94	77.7	9.9	—	—	—	—	—	—
HT-PL637-18	3.9	12.0	0.828	68.5	6.1	—	—	—	—	—	—
HT-PL637-20	3.0	12.5	0.800	66.2	4.8	—	—	—	—	—	—
HT-PL637-22	2.7	11.3	0.872	72.1	7.1	14.4	12.5(-13)	—	109	89(-18)	—
HT-PL637-23	2.6	10.8	0.892	73.7	5.0	12.2	11.6(-5)	5.9(-52)	110	105(-5)	62(-44)
HT-PL637-24	2.6	10.8	0.892	73.7	5.6	12.3	12.7(+3)	6.5(-47)	112	116(+4)	65(-42)
HT-PL637-25	2.6	10.0	0.940	77.7	7.9	13.5	11.9(-12)	—	122	108(-11)	—
HT-PL637-26	4.3	13.0	0.773	63.9	2.6	15.2	14.7(-3)	—	106	111(+5)	—
HT-PL637-27	3.6	12.5	0.800	66.2	3.3	14.8	13.8(-7)	7.9(-47)	100	102(+2)	56(-44)
HT-PL637-28	3.0	11.2	0.876	72.4	6.3	13.6	12.7(-7)	5.5(-60)	112	109(-3)	57(-49)
HT-PL637-29	3.3	11.5	0.856	70.8	7.5	—	—	—	—	—	—

* Hydrolytic Ageing for 125 hours at 85°C and 97% RH

** Values in ( ) represent percent change from untreated

CONCLUSIONS

1. Attempts to prepare stable, open cell foams based on polybutadiene polyol as the sole polyol were not successful. Even though polybutadiene polyol contains mostly primary hydroxyl groups, it generally reacted slower than polyether polyols containing less reactive secondary hydroxyl groups. One possible reason polybutadiene polyol reacts slower than expected is its immiscibility with the water of reaction. Another reason could be the lack of a suitable surfactant. Commercial surfactants have been tailored for use in polyether and/or polyester formulations. Polybutadiene polyol's chemical makeup differs significantly from above.

2. While the addition of a reactive tertiary amine containing polyether polyol to a polybutadiene polyol formulation increased the reactivity of the mix, stable, open cell foams could not be prepared.

3. The most stable polybutadiene foams resulted from the addition of a polymer polyol (or grafted polyol) to the formulation. Still, these foams were mostly closed cell and had relatively poor strength.

4. Foams prepared from polybutadiene polyol in combination with other polyols were generally characterized by having a high percentage of closed cells and insufficient tensile strength to meet MIL-F-81334B (AS). While vibration damping properties varied depending on the formulation, the foams had excellent hydrolytic stability but poor resistance to hydraulic fluid.

ACKNOWLEDGMENTS

The authors would like to thank Robert Williams and Robert N. Peterson for determining the vibration damping properties of the foams. Arthur Harris prepared the vibration damping specimens, and George Green helped measure the mechanical properties of the foams.

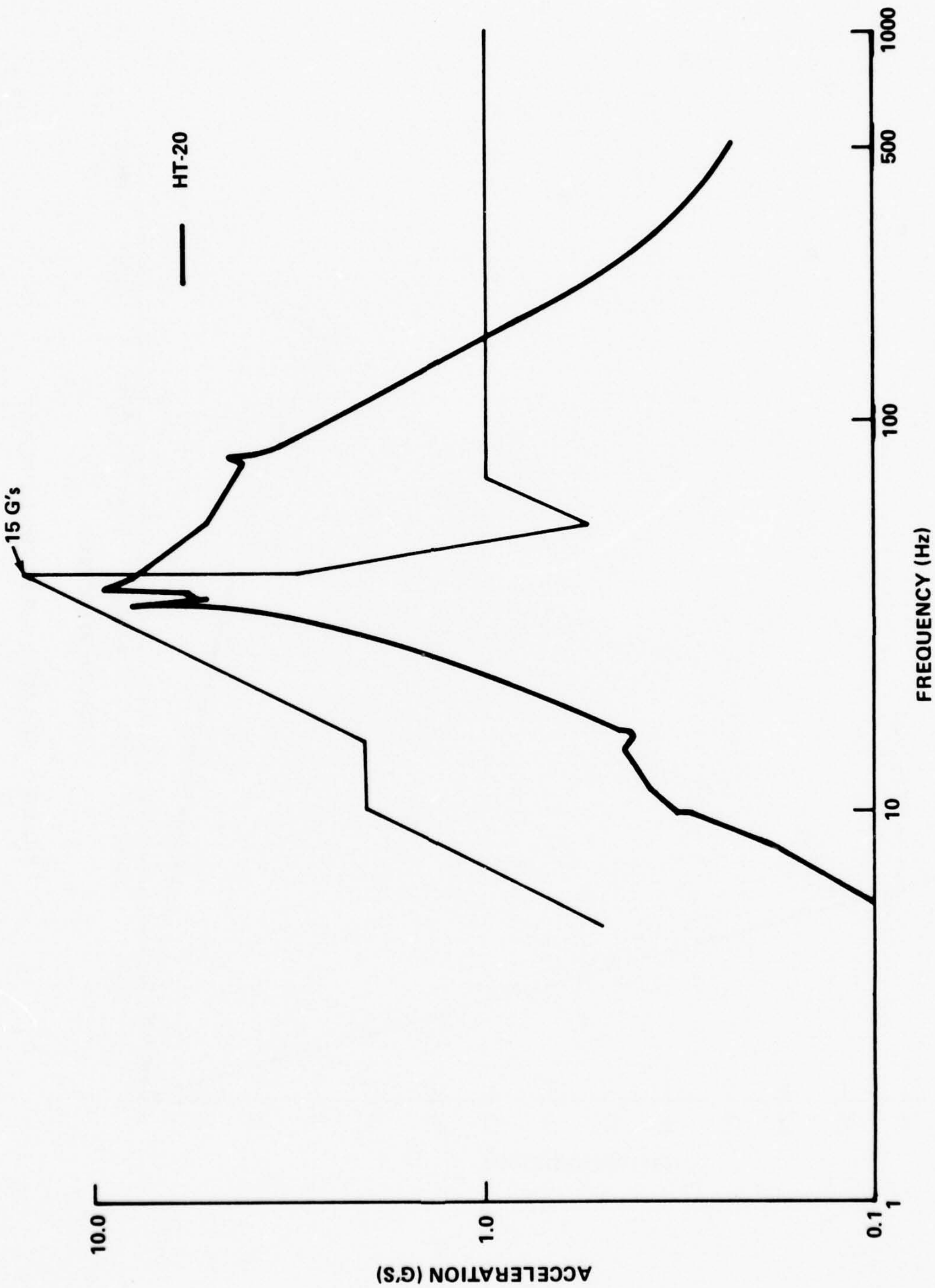

FIGURE 1. VIBRATION DAMPING CURVE FOR HT-20

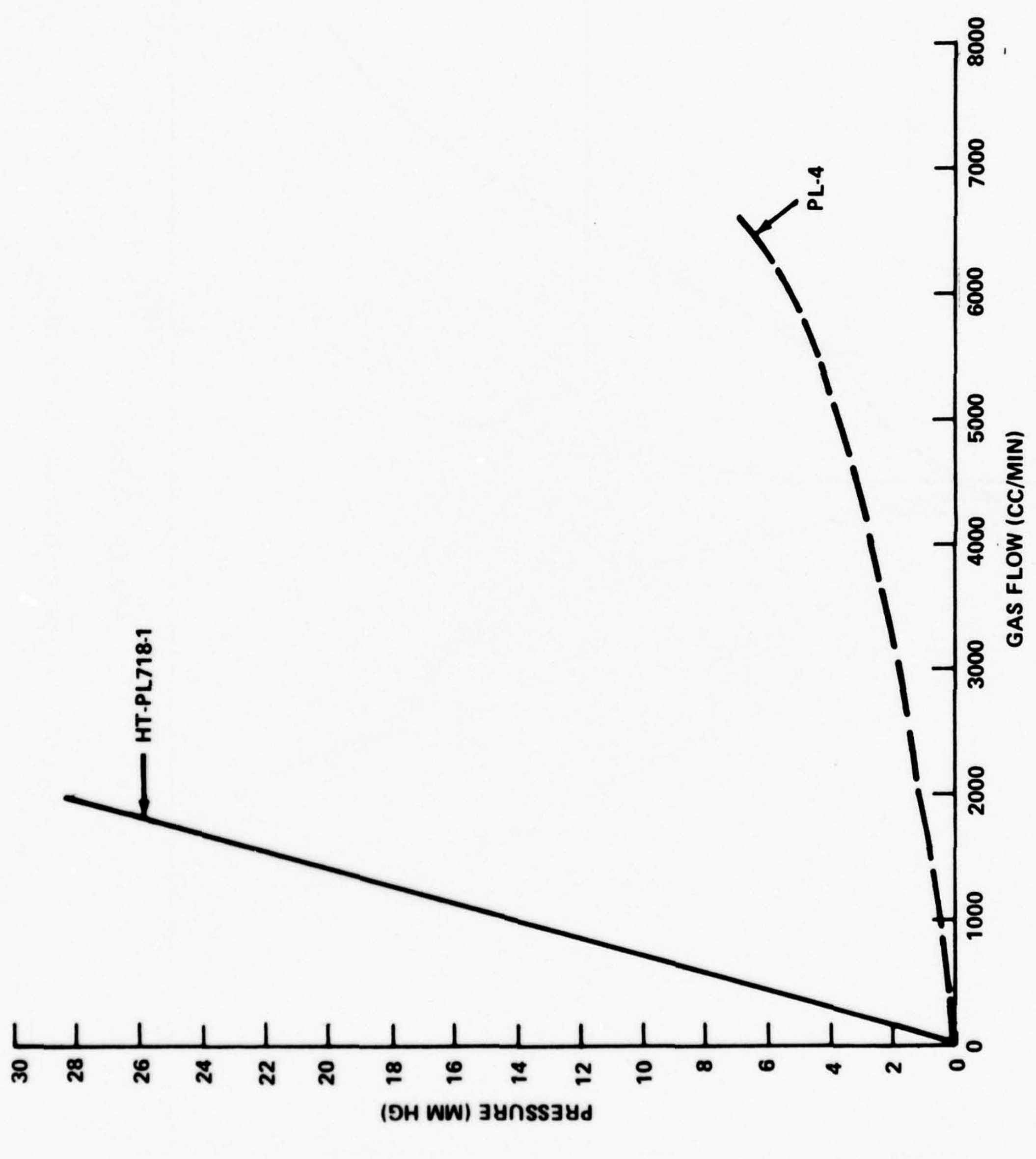

FIGURE 2. GAS FLOW CURVE FOR HT-PL718-1

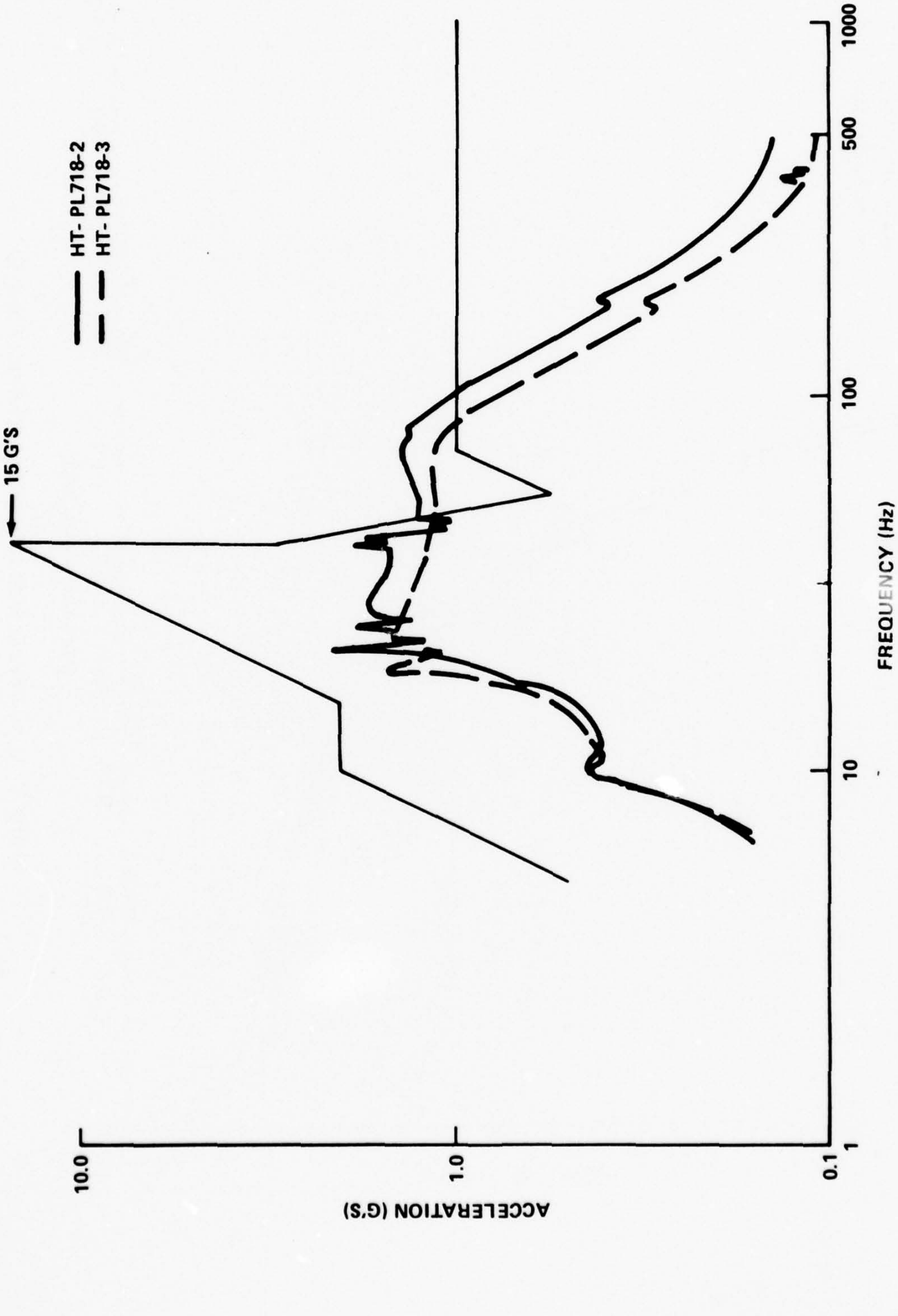

FIGURE 3. VIBRATION DAMPING CURVES FOR HT-PL718-2 AND 3

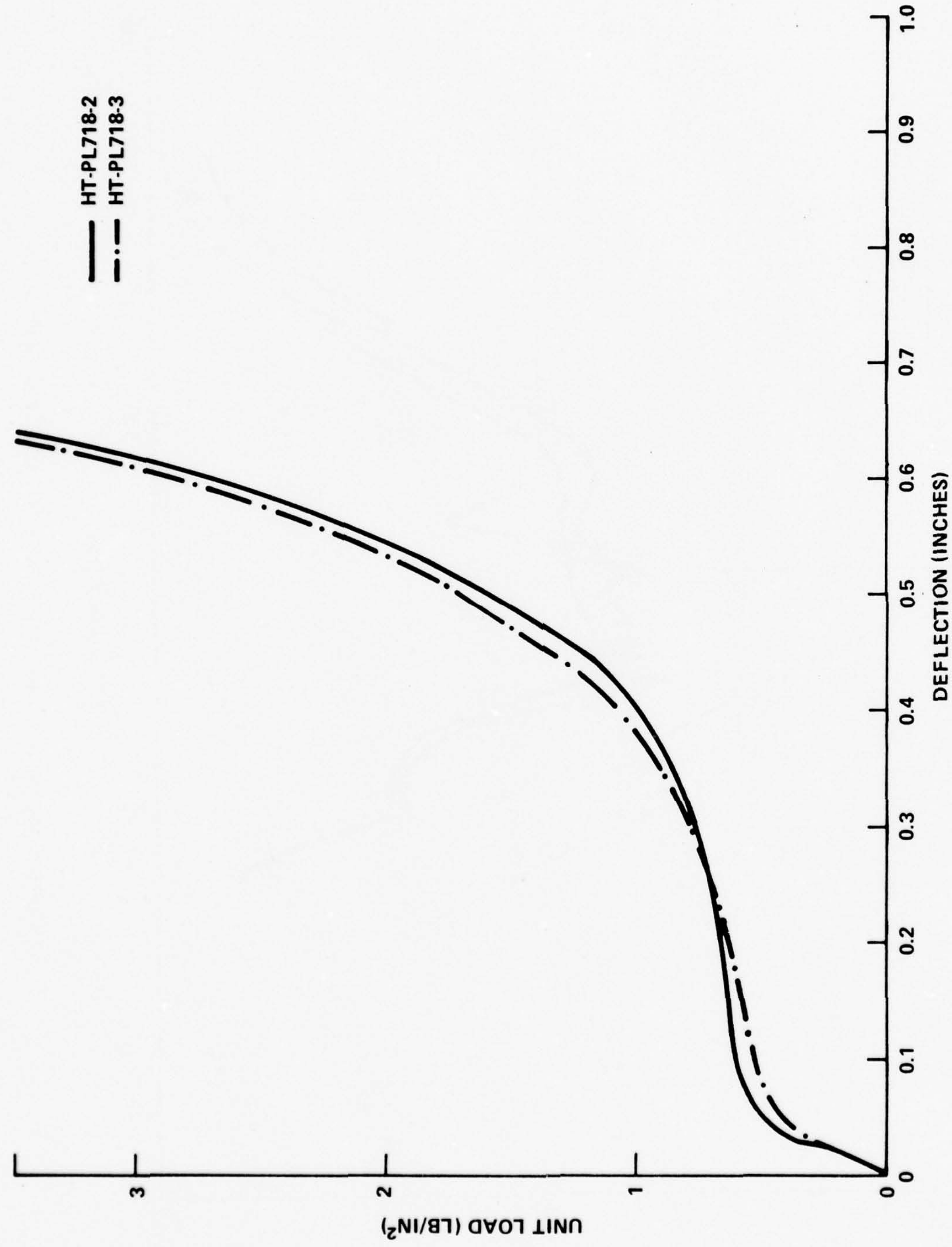

FIGURE 4. LOAD DEFLECTION CURVES FOR HT-PL718-2 AND 3

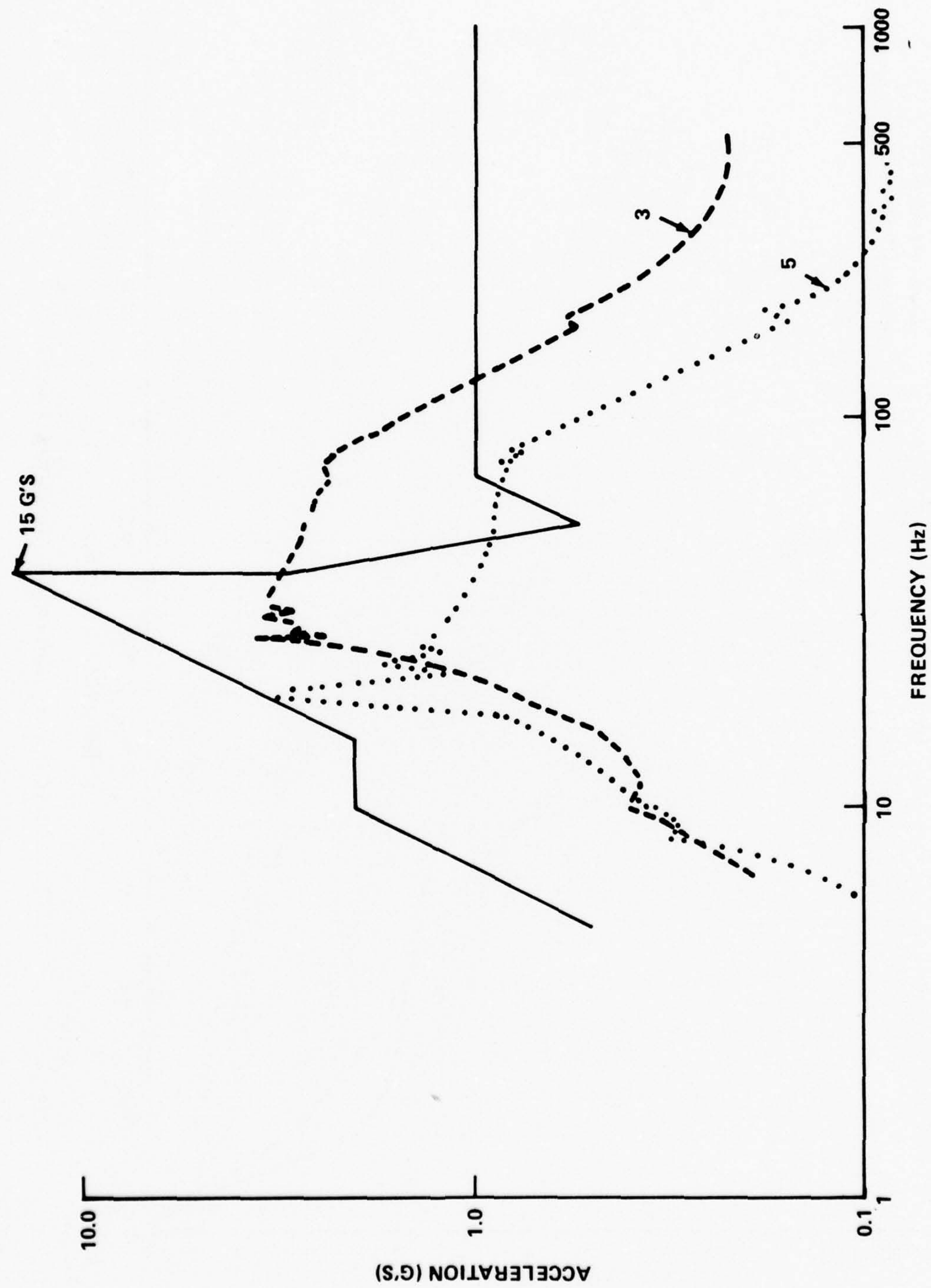

FIGURE 5. VIBRATION DAMPING CURVES FOR HT-PM-3 AND 5

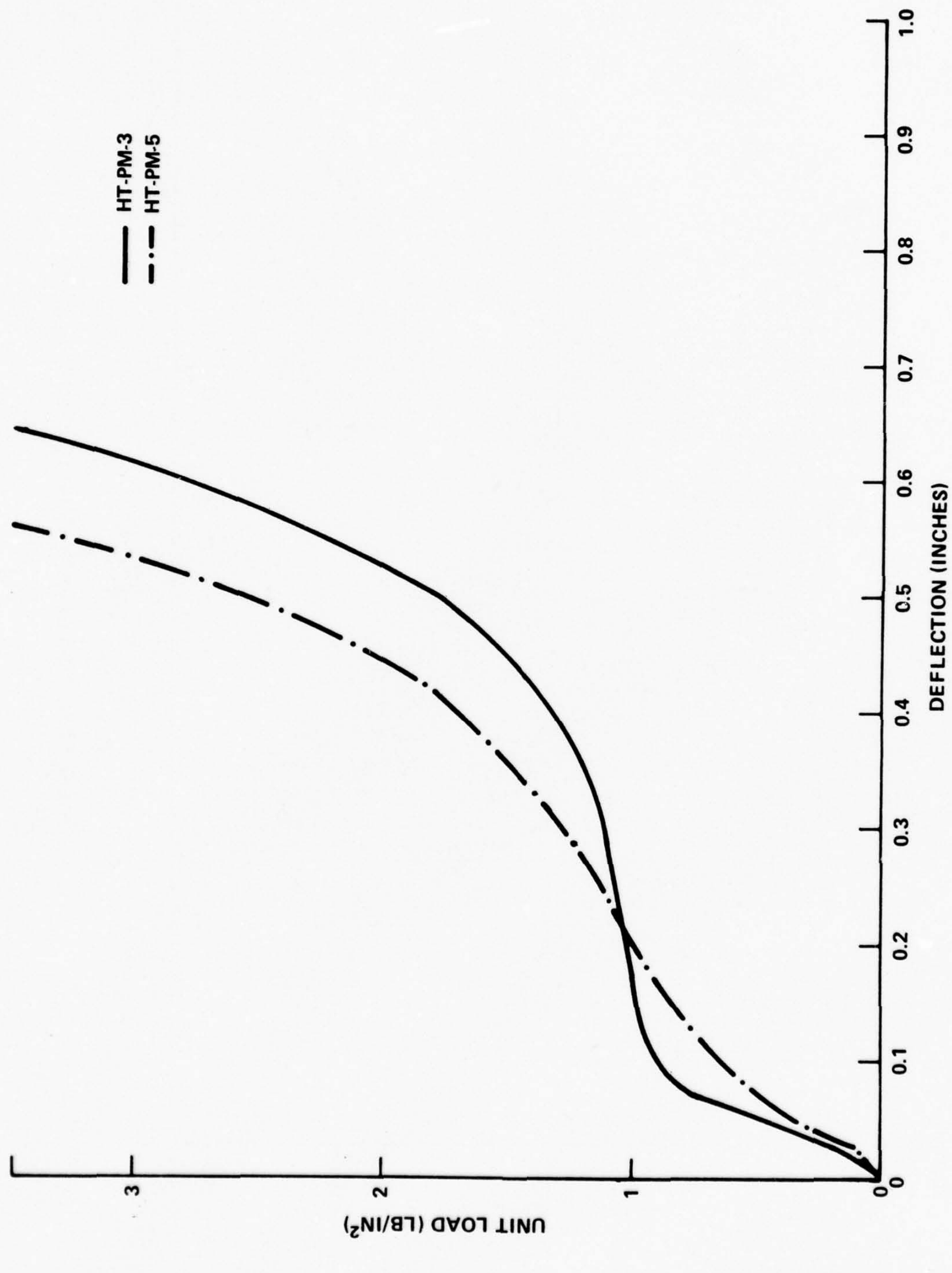

FIGURE 6. LOAD DEFLECTION CURVES FOR HT-PM-3 AND 5

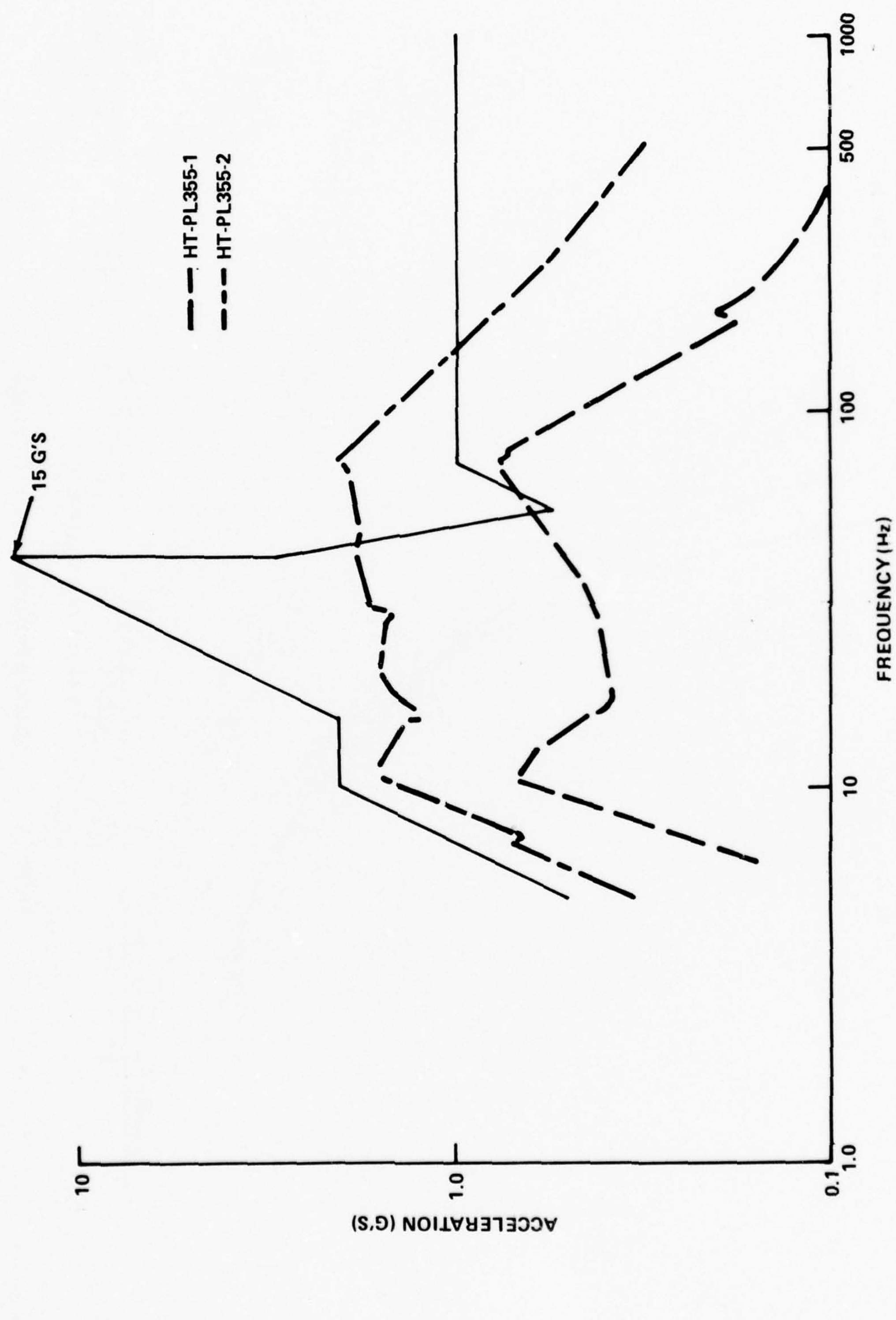

FIGURE 7. VIBRATION DAMPING CURVES FOR HT-PL355-1 AND 2

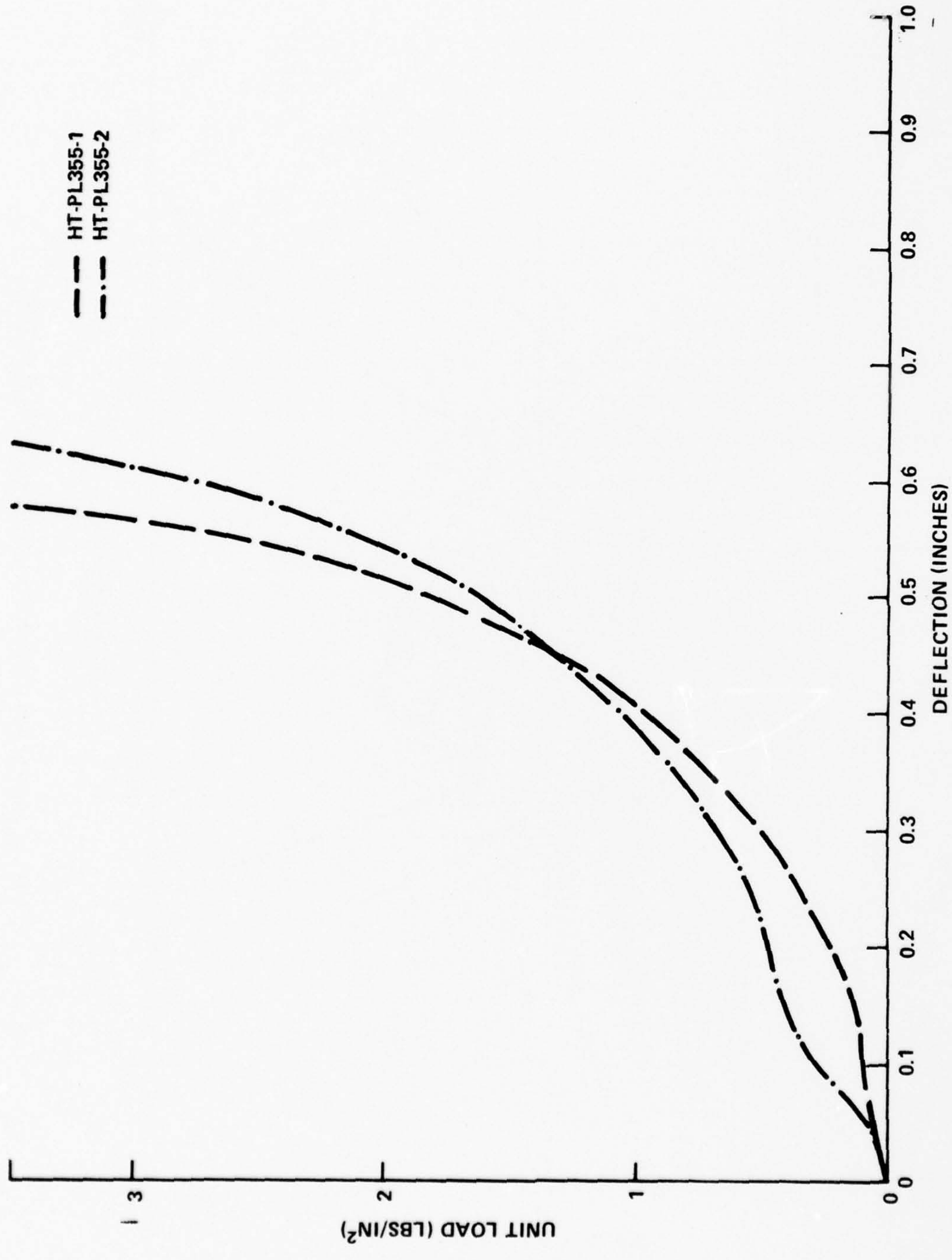

FIGURE 8. LOAD DEFLECTION CURVES FOR HT-PL-355-1 AND 2

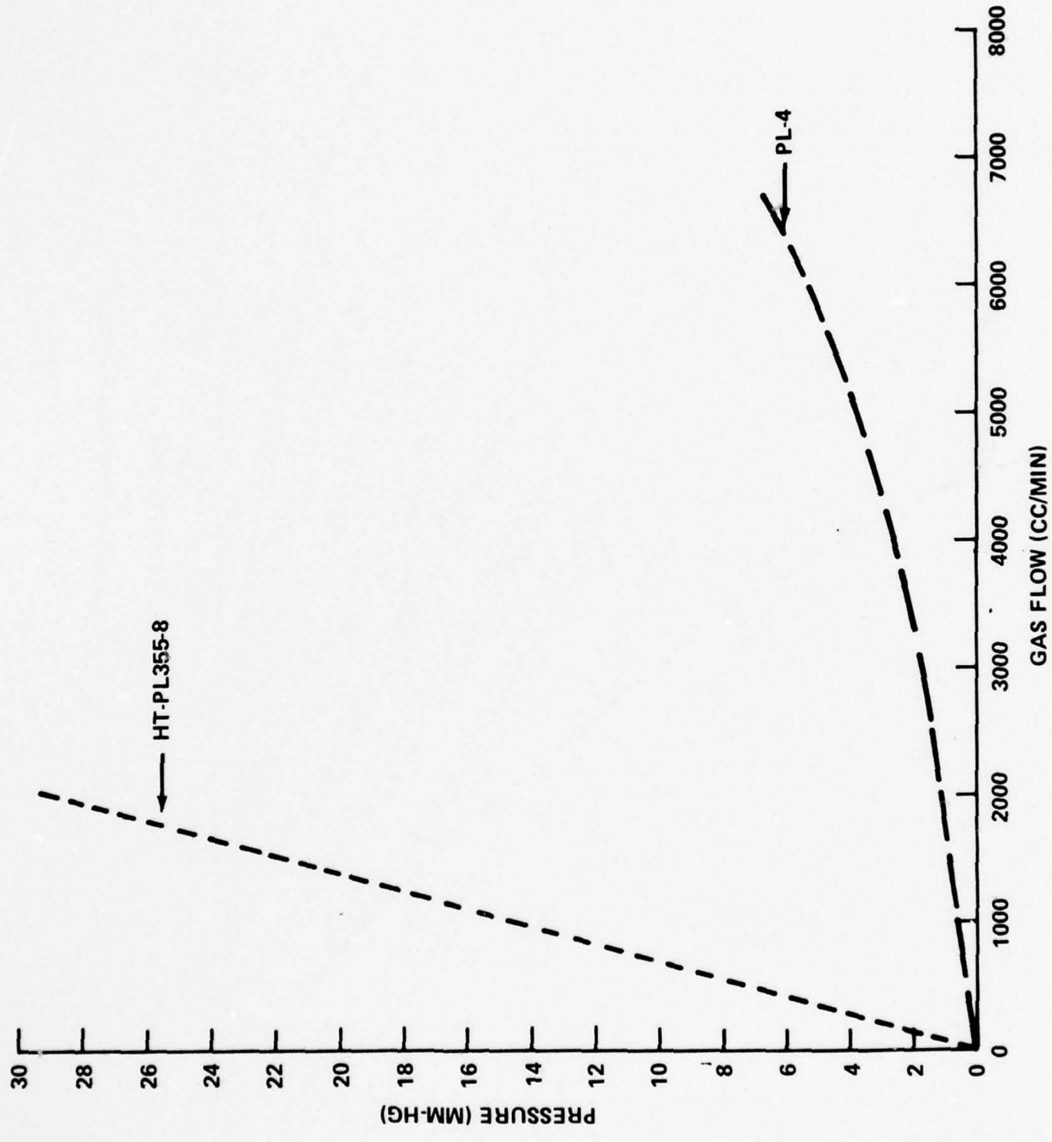

FIGURE 9. GAS FLOW CURVE FOR HT-PL355-8

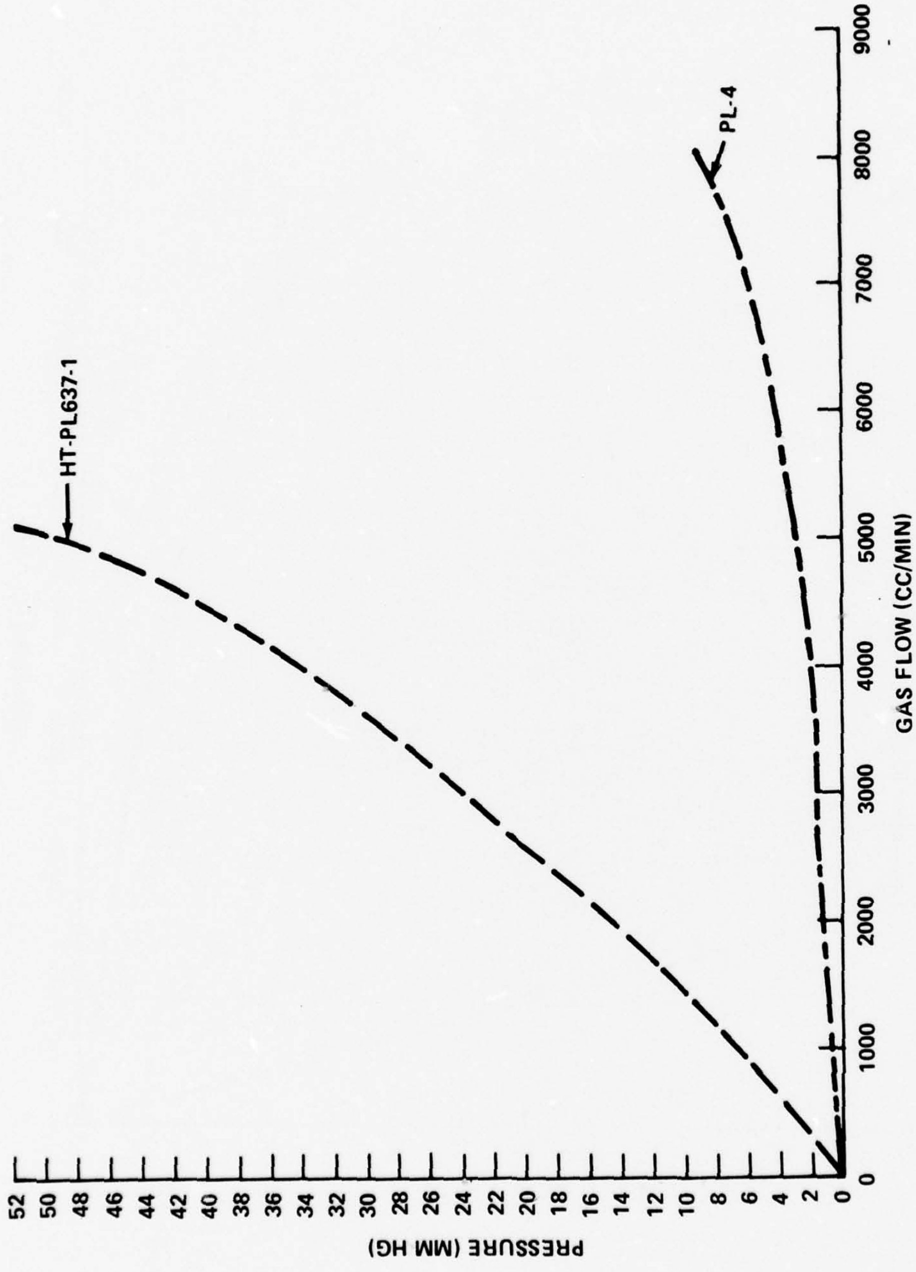

FIGURE 10. GAS FLOW CURVE FOR HT-PL637-1

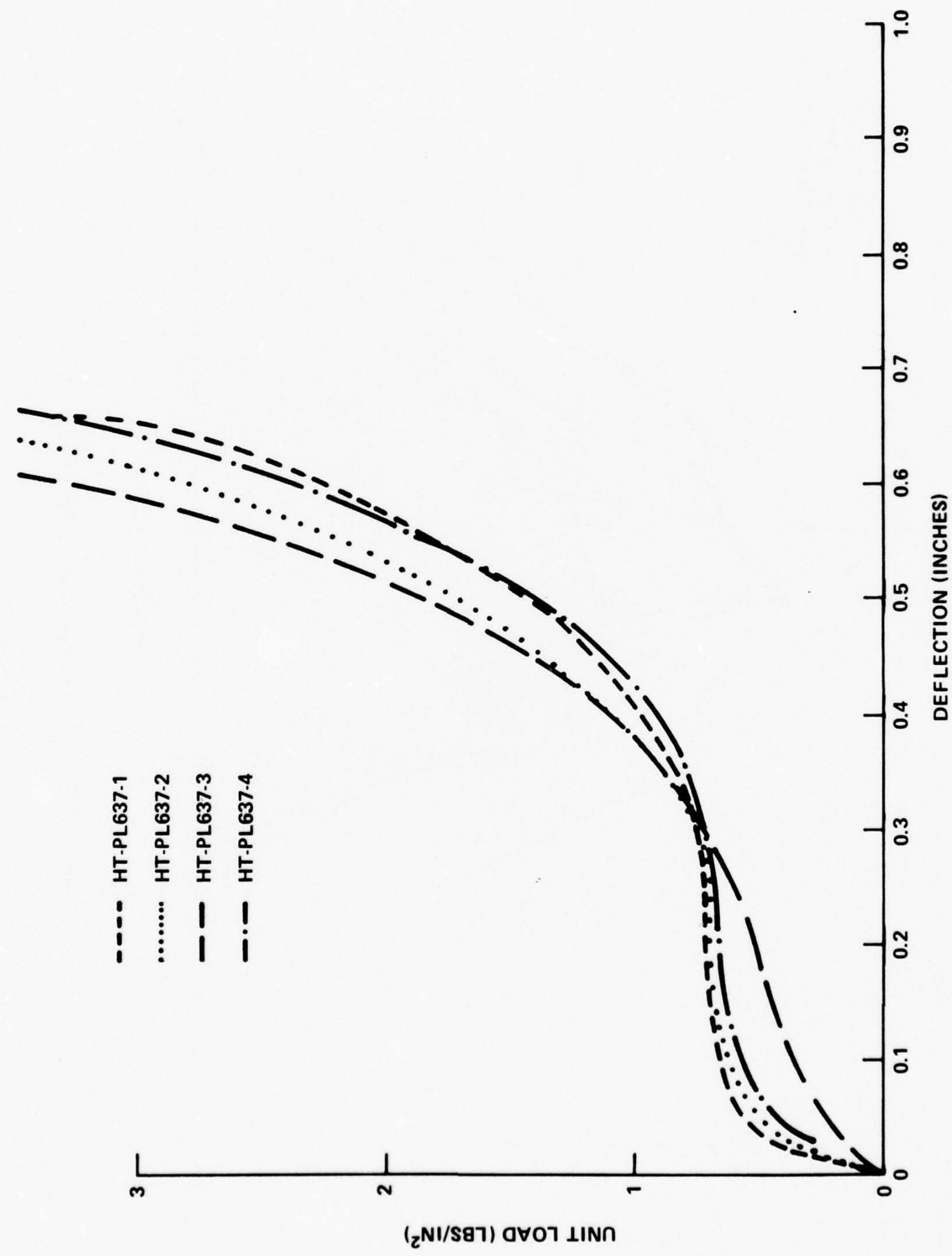

FIGURE 11. LOAD DEFLECTION CURVE FOR HT-PL637-1 TO 4

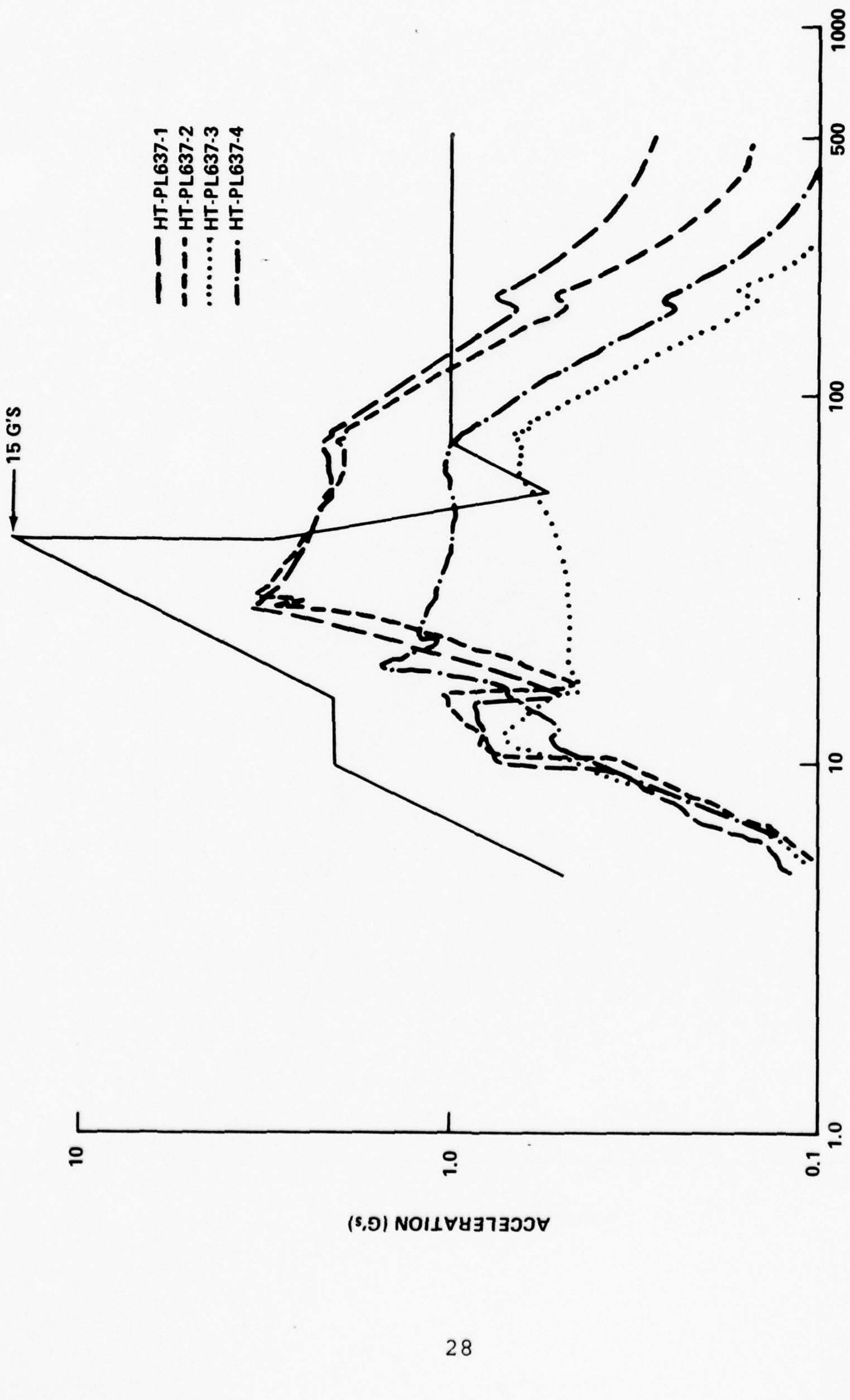

FIGURE 12. VIBRATION DAMPING CURVES FOR HT-PL637-1 TO 4

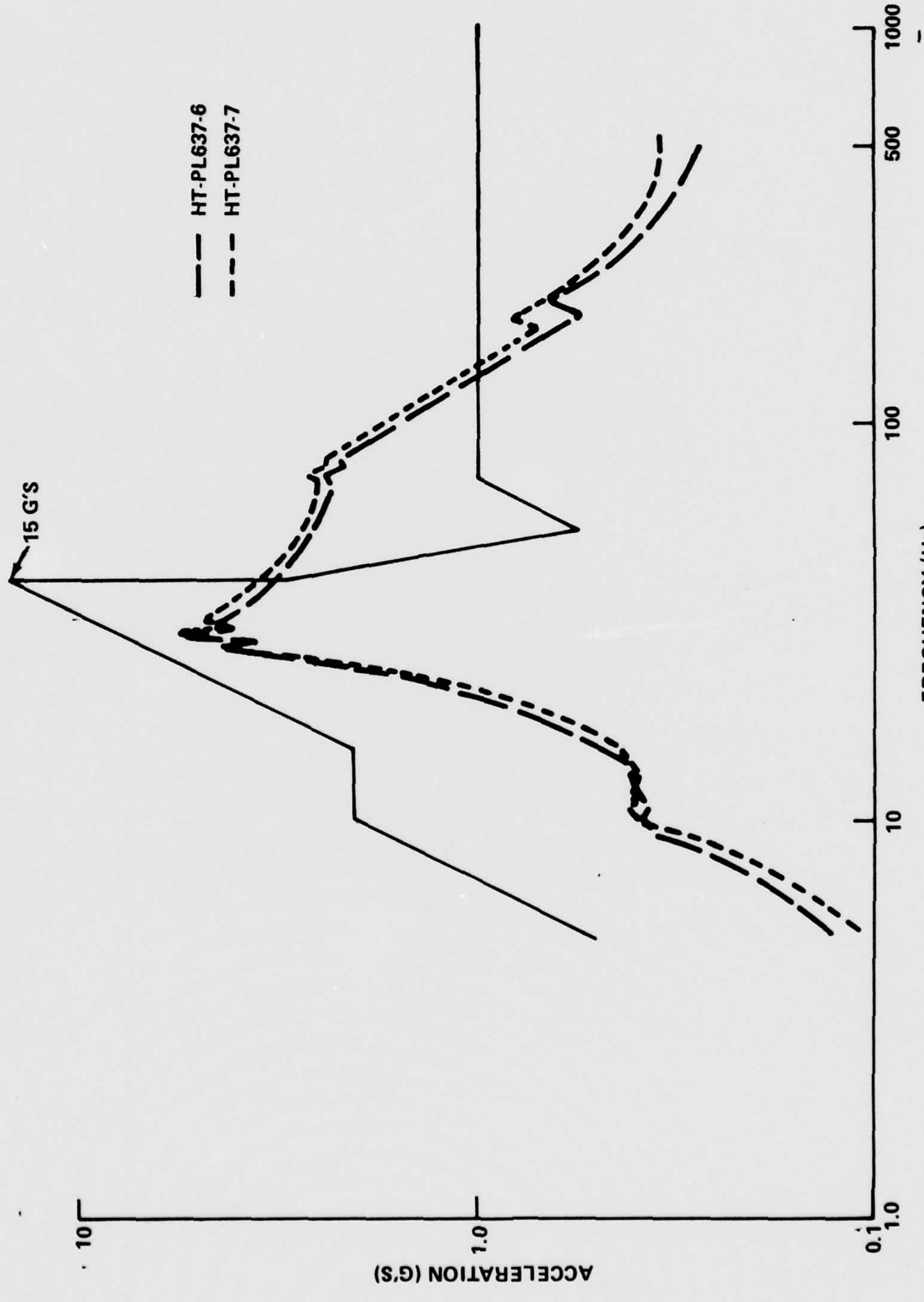

FIGURE 13. VIBRATION DAMPING CURVES FOR HT-PL637-6 AND 7

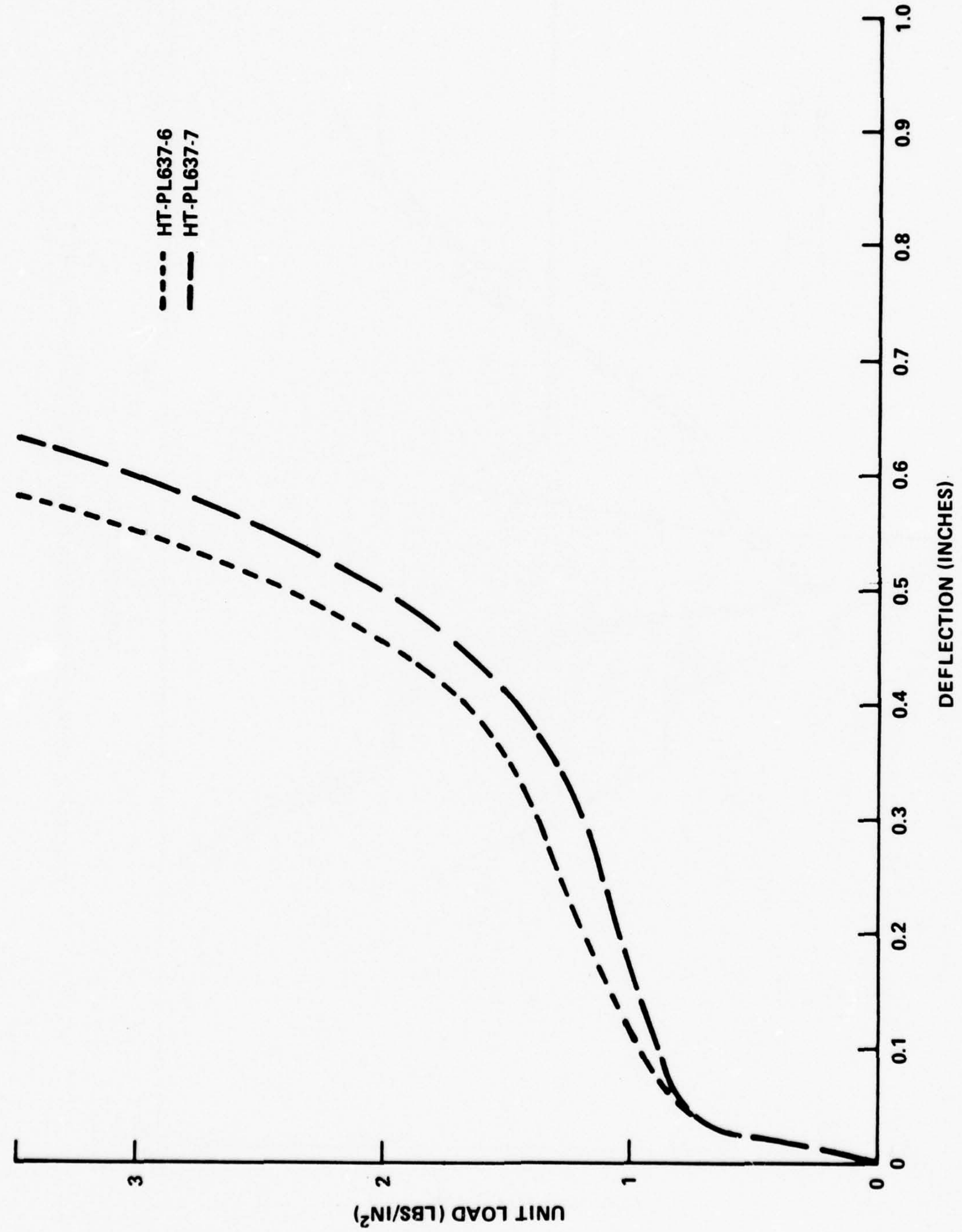

FIGURE 14. LOAD DEFLECTION CURVES FOR HT-PL637-6 AND 7

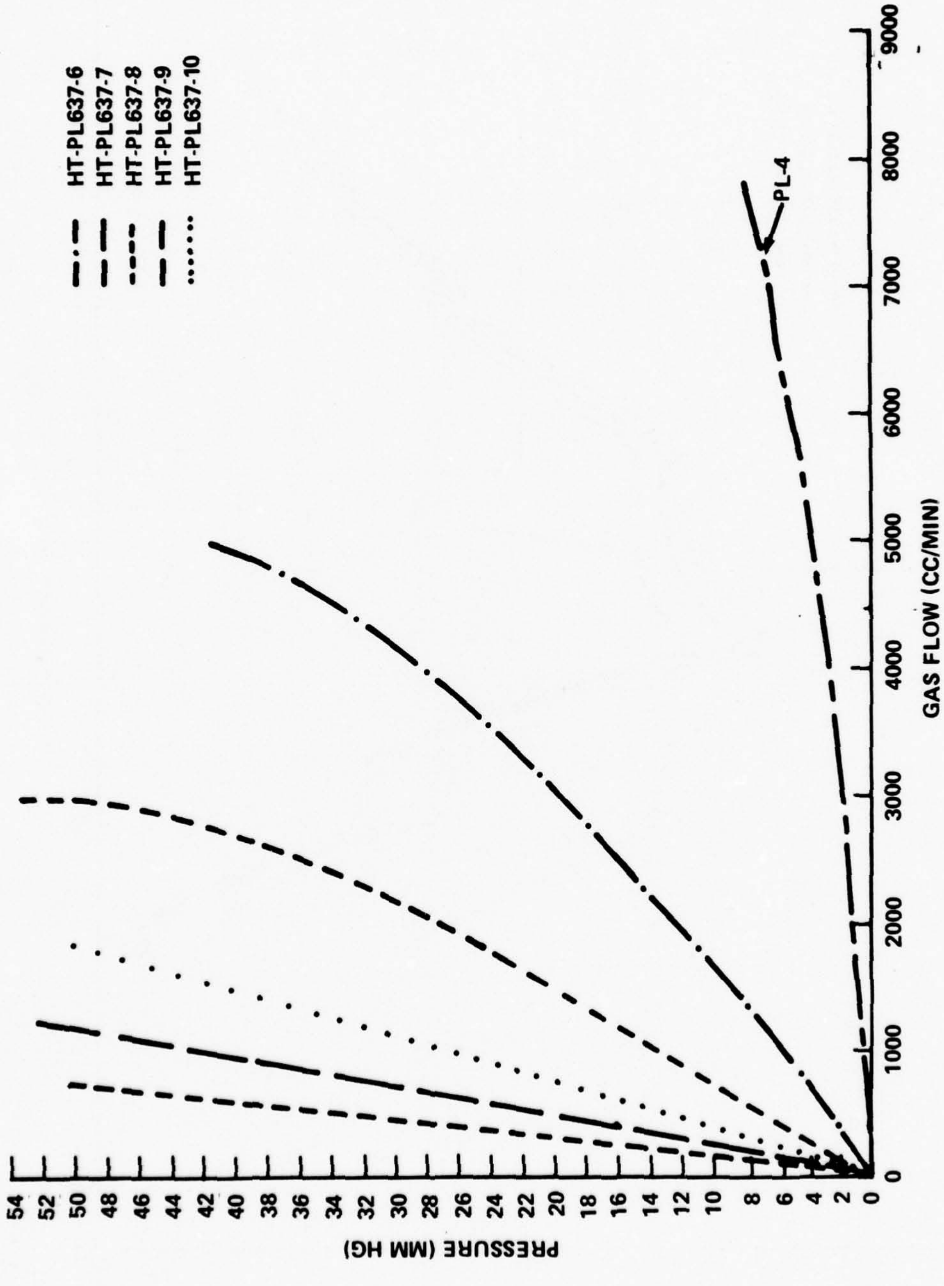

FIGURE 15. GAS FLOW CURVES FOR HT-PL637-6 TO 10

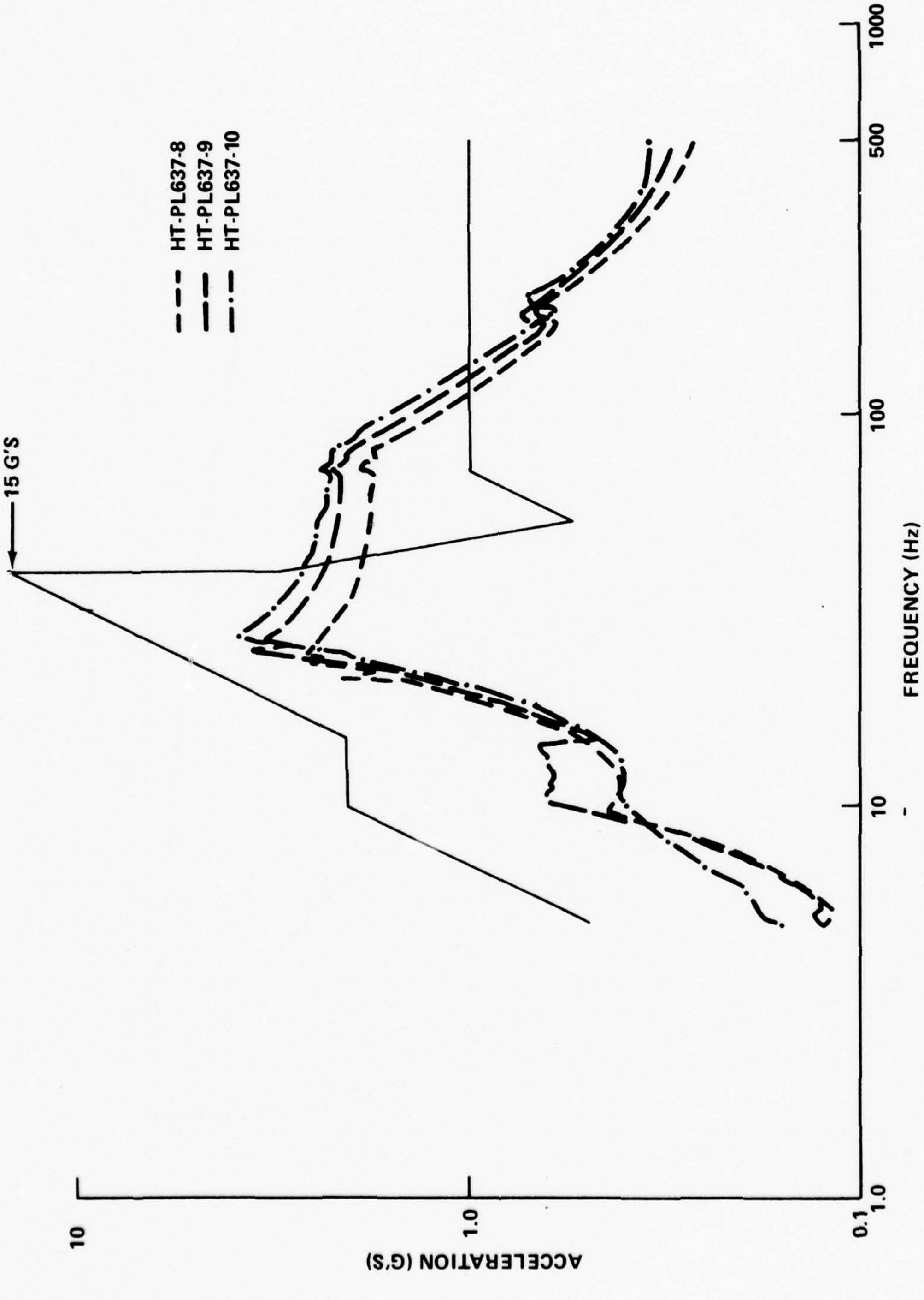

FIGURE 16. VIBRATION DAMPING CURVES FOR HT-PL637-8 TO 10

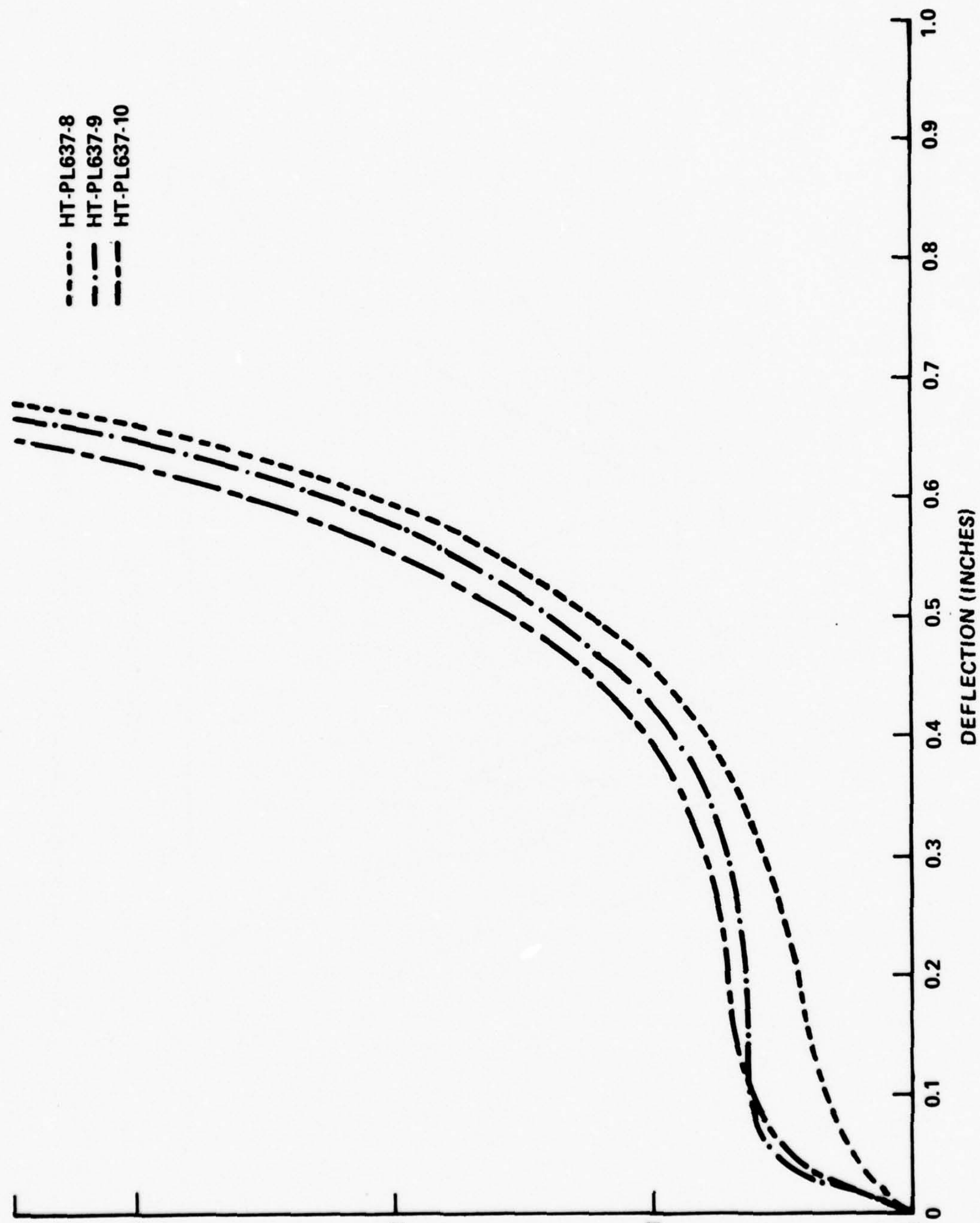

FIGURE 17. LOAD DEFLECTION CURVES FOR HT-PL637-8 TO 10

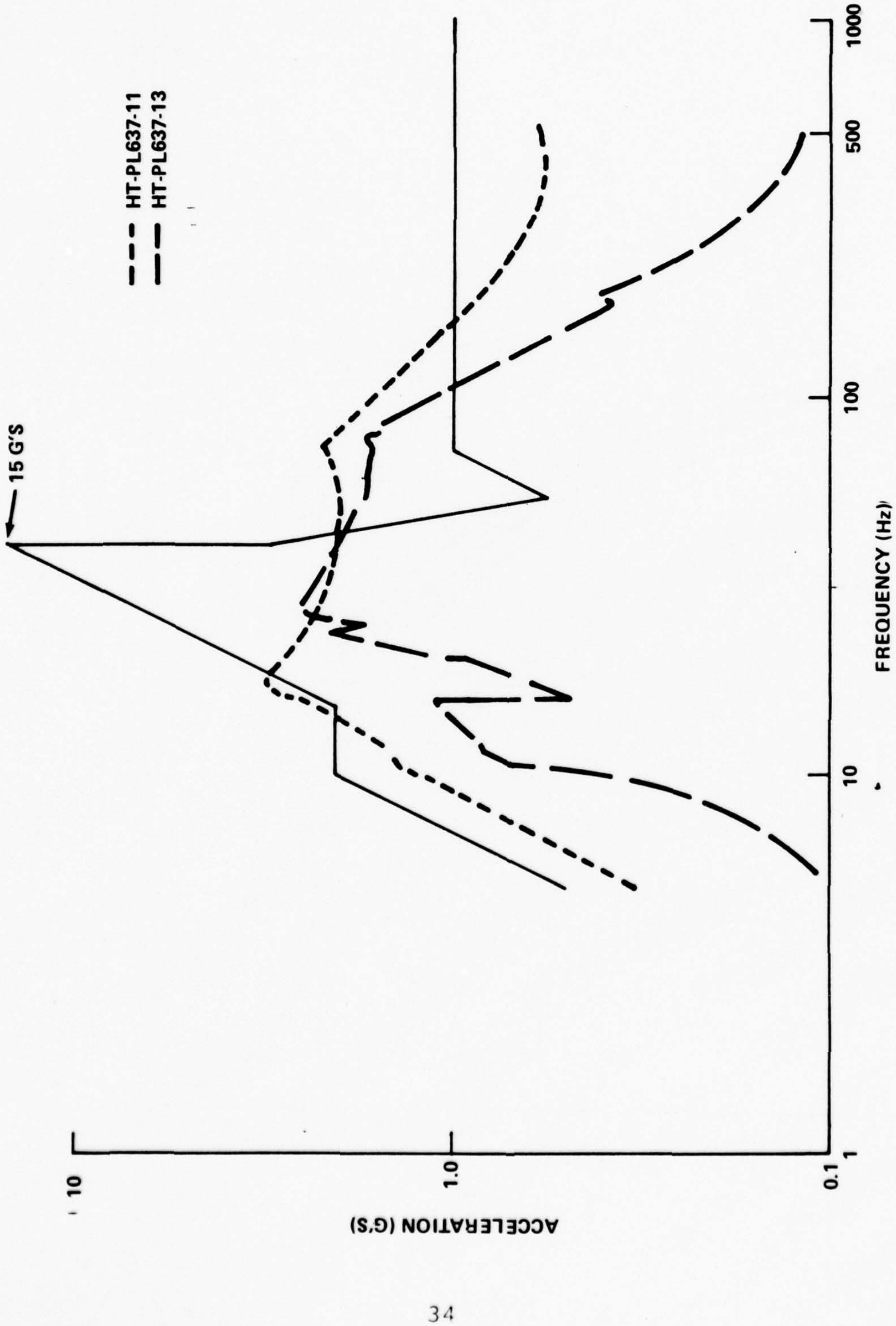

FIGURE 18. VIBRATION DAMPING CURVES FOR HT-PL637-11 AND 13

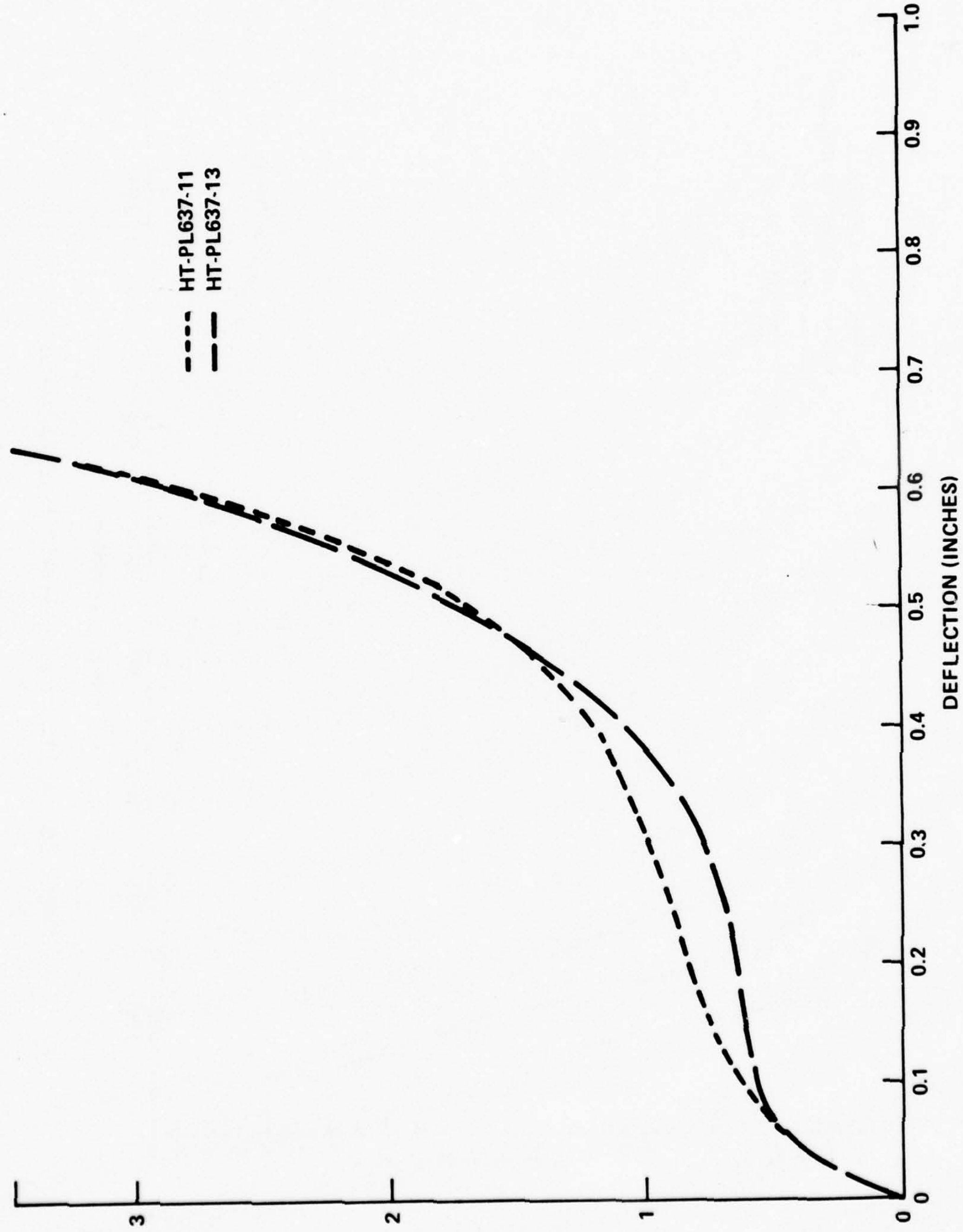

FIGURE 19. LOAD DEFLECTION CURVES FOR HT-PL637-11 AND 13

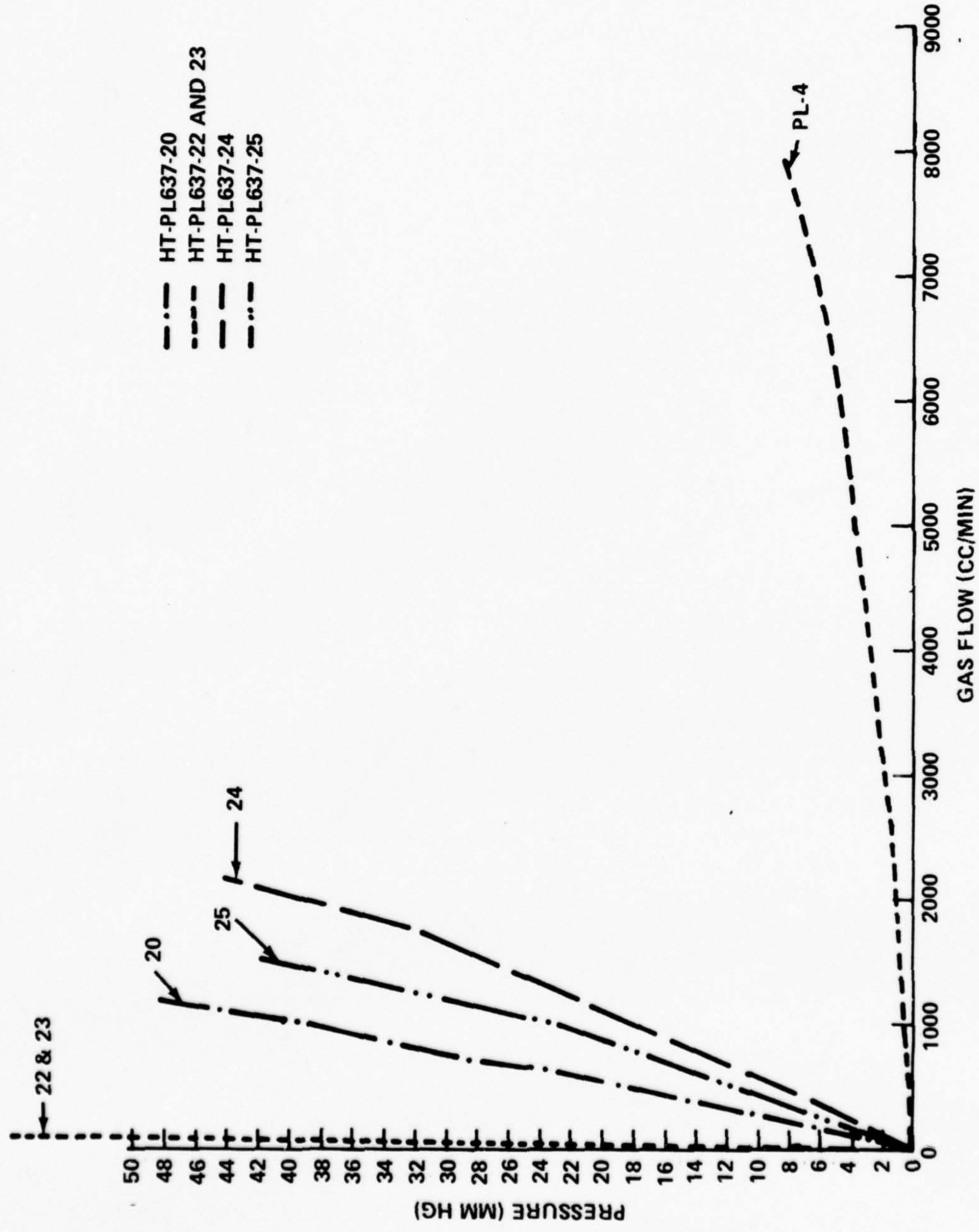

FIGURE 20. GAS FLOW CURVES FOR HT-PL637-20 AND 22 TO 25

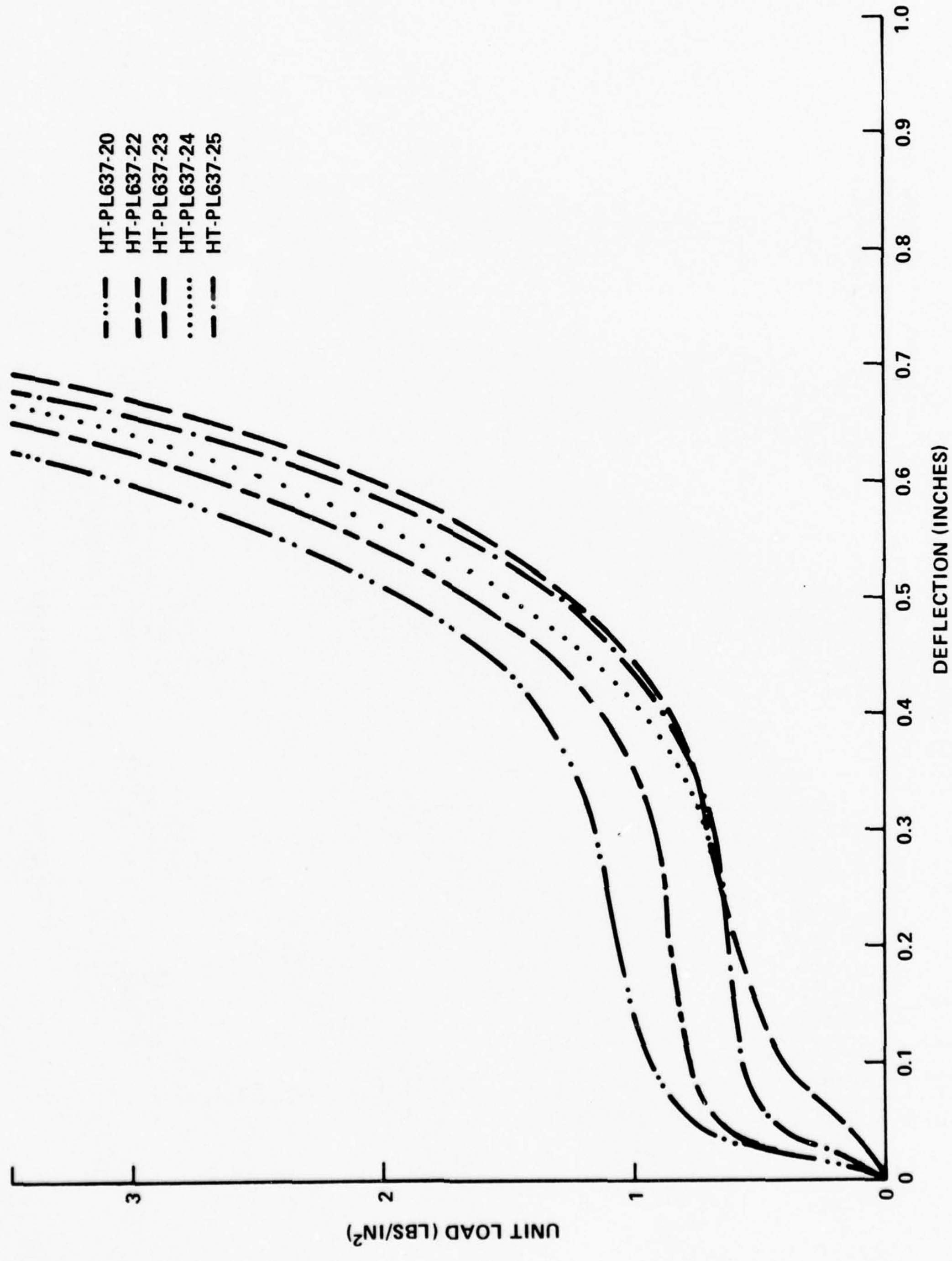

FIGURE 21. LOAD DEFLECTION CURVES FOR HT-PL637-20 AND 22 TO 25

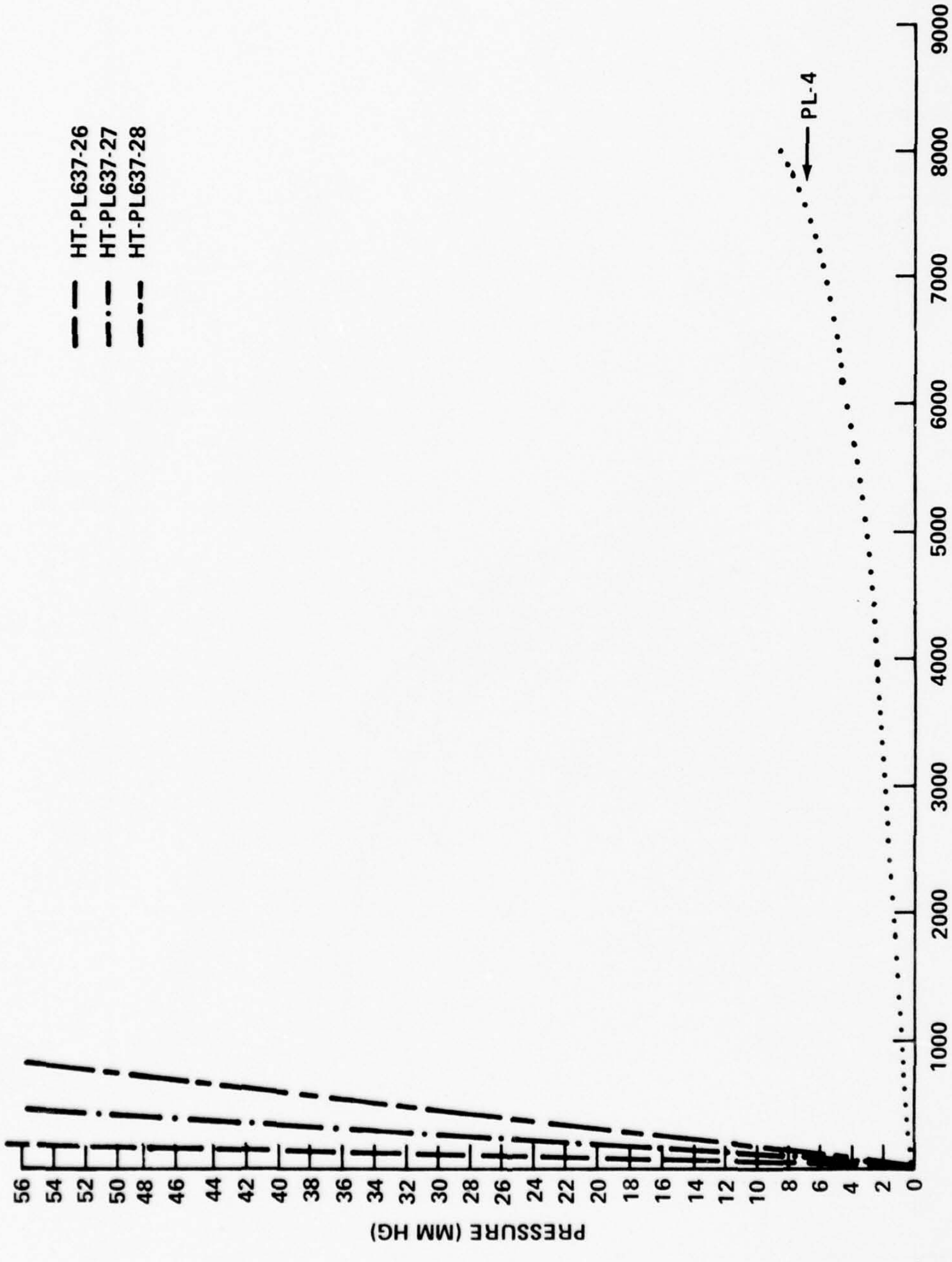

FIGURE 22. GAS FLOW CURVES FOR HT-PL637-26 TO 28

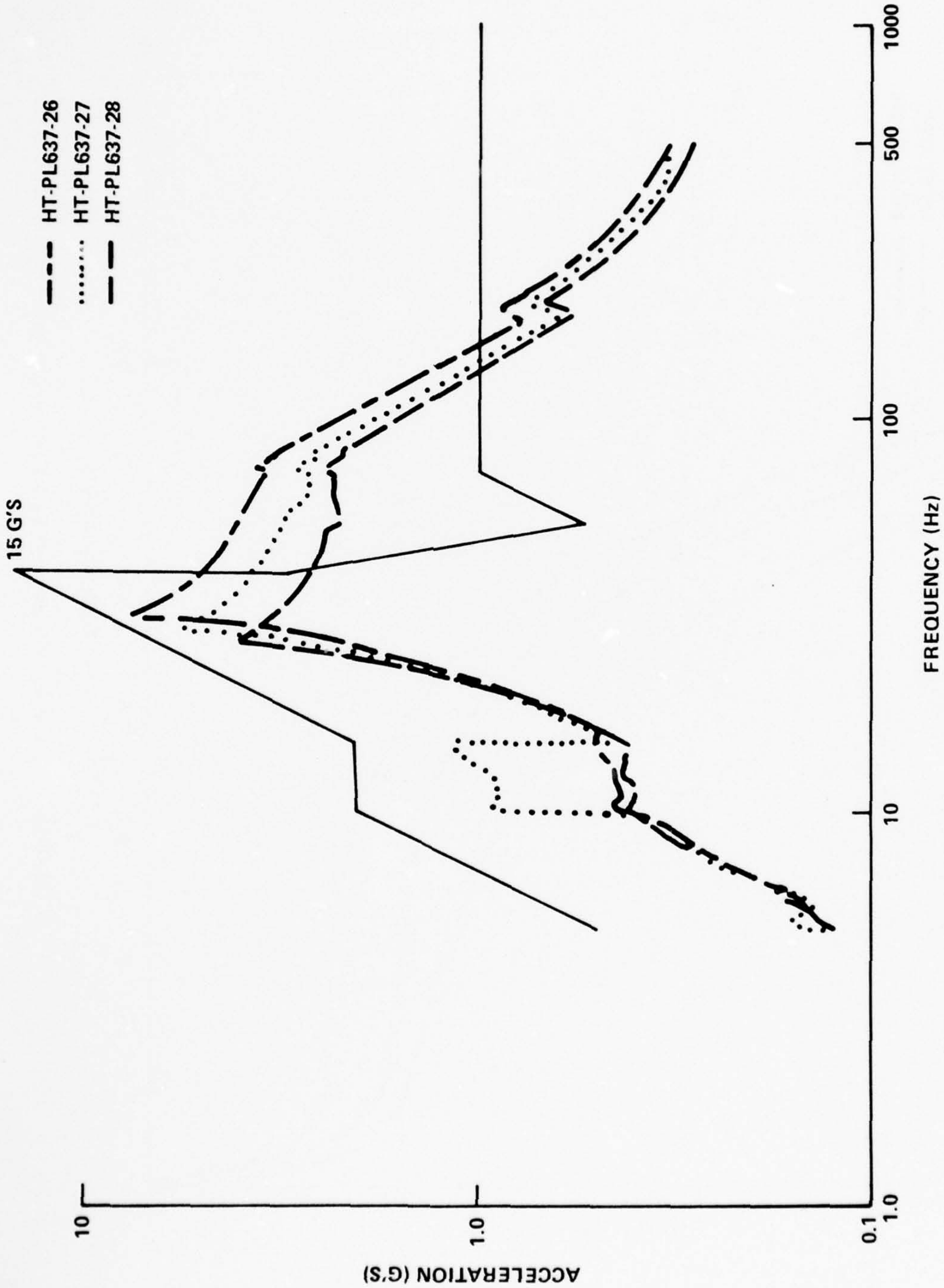

FIGURE 23. VIBRATION DAMPING CURVES FOR HT-PL637-26 TO 28

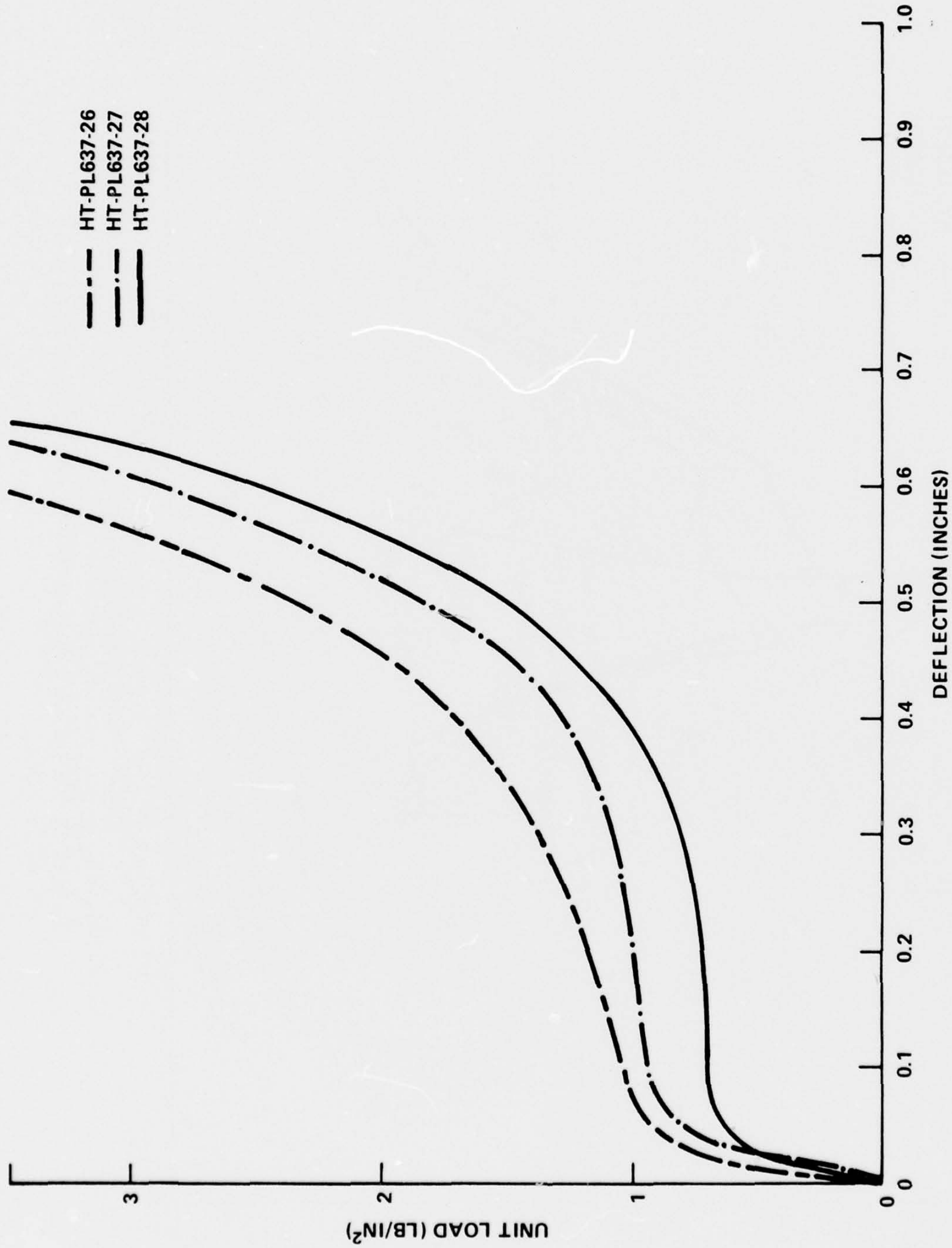

FIGURE 24. LOAD DEFLECTION CURVES FOR HT-PL637-26 TO 28

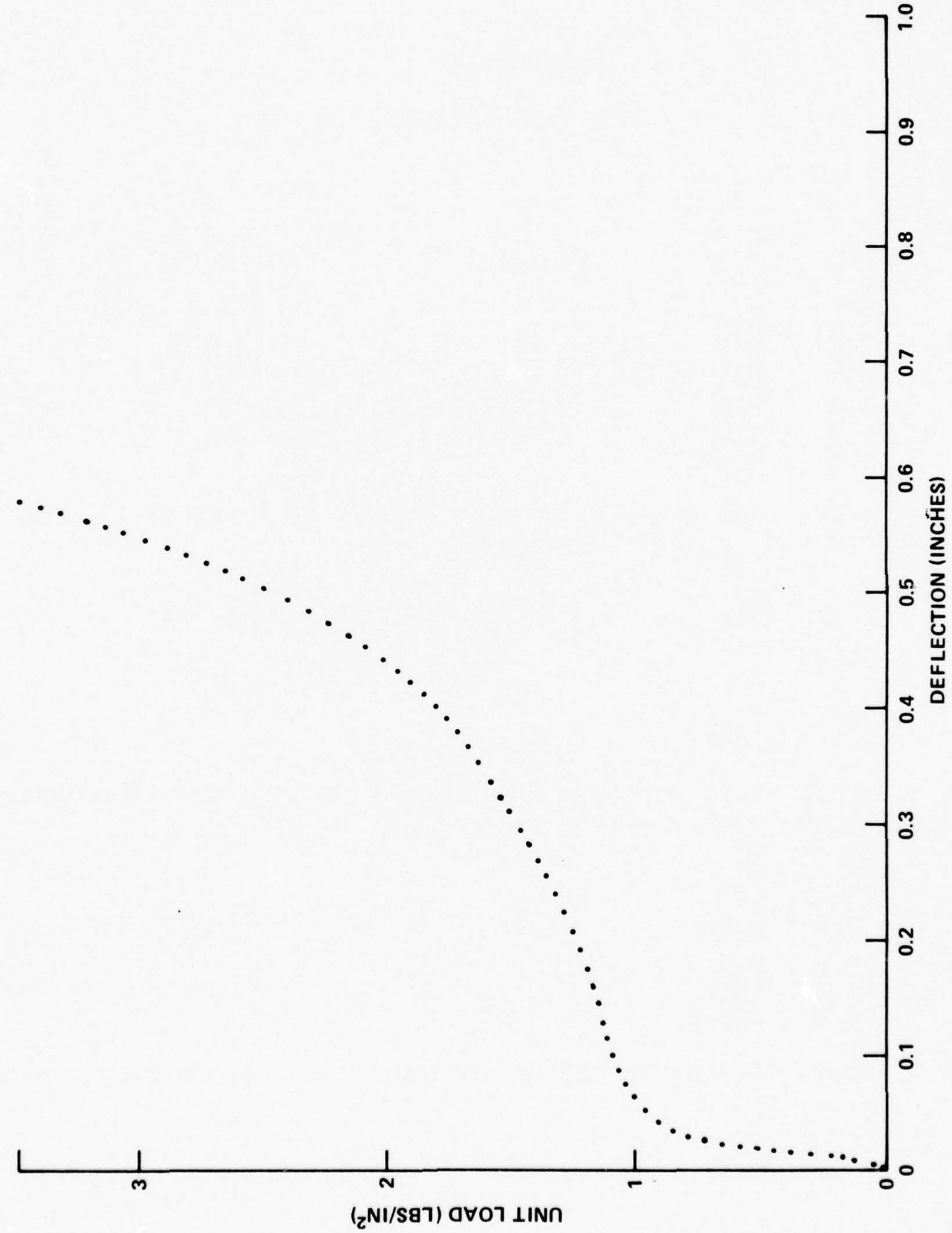

FIGURE 25. LOAD DEFLECTION CURVE FOR HT-PL637-29

Appendix A

FOAM FORMULATIONS

HT-Foams

<u>HT-1</u>

100	HT
33.44	TDI
2.5	H_2O
0.3	T-9
0.2	33LV
0.8	DC198

Hand mix 20 sec.; room temperature gave little or no rise; 15 min. at 100°C and 30 min. at 125°C; collapse

<u>HT-2</u>

100	HT
33.44	TDI
2.5	H_2O
0.3	T-9
0.2	33LV
0.8	DC198

Hand mix 30 sec.; at 125°C; some shrinkage in middle but improvement over HT-1; coarse, mostly closed cell

<u>HT-3</u>

100	HT
33.44	TDI
2.5	H_2O
0.5	T-9
0.2	33LV
0.8	DC198

Hand mix 30 sec., 45 min. at 125°C; internal fissure; coarse, closed cell

HT-4	100	HT
	28.4	TDI
	2	H_2O
	0.3	T-9
	0.2	33LV
	0.8	DC198

Hand mix; 30 min. at 125°C; shrinkage; coarse, closed cell

HT-5	100	HT
	28.4	TDI
	2	H_2O
	0.3	T-12
	0.2	33LV
	0.8	DC198

Hand mix; creamed faster with T-12 than T-9; internal fissure; extremely coarse, closed cell

HT-6	100	HT
	28.4	TDI
	2	H_2O
	0.3	T-12
	0.4	33LV
	0.8	DC198

Hand mix; fast cream and set; internal fissure; coarse, closed cell

HT-7	100	HT
	28.4	TDI
	2	H_2O
	0.2	T-12
	0.4	33LV
	1.5	DC198

Hand mix; cream and set fast; internal fissure; mostly closed cell

HT-8	200	HT
	56.8	TDI
	4	H_2O
	0.3	T-12
	0.8	33LV
	3	DC198

Hand mix; cream and set fast; internal fissure; mostly closed cell

HT-9	200	HT
	56.8	TDI
	4	H_2O
	0.2	T-12
	0.8	33LV
	3	DC198

Stirrer mix; fast cream and set; internal fissure; closed cell

HT-10	100	HT
	28.4	TDI
	2	H_2O
	0.2	T-12
	0.5	33LV
	1.5	DC198

Hand mix; fast cream and set; some shrinkage; comparable to HT-7; one of better HT foams, mostly closed cell

HT-11	200	HT
	56.8	TDI
	4	H_2O
	0.4	T-12
	1.0	33LV
	3	DC198

Stirrer mix; 30 min. at 125^{o}C; internal fissure; closed cell

HT-12	200	HT
	56.8	TDI
	4	H_2O
	0.25	T-12
	1.0	33LV
	3	DC198

Stirrer mix; 30 min. at 125^{o}C; internal fissure; mostly closed cell

HT-13	200	HT
	56.8	TDI
	4	H_2O
	0.25	T-12
	1.3	33LV
	3	DC198

Stirrer mix; 30 min. at 125^{o}C; internal fissure; mostly closed cell

HT-14	50	HT
	14.2	TDI
	1	H_2O
	0.27	T-12
	0.25	33LV
	0.75	DC198

Stirrer mix; 30 min. at 125°C, internal fissure; severe shrinkage upon cooling

HT-15	50	HT
	14.2	TDI
	1	H_2O
	0.13	T-12
	0.5	33LV
	0.75	DC198

Stirrer mix; 30 min. at 125°C; internal fissure; severe shrinkage upon cooling

HT-16	100	HT
	25.4	TDI
	1.75	H_2O
	0.2	T-12
	0.5	33LV
	1.0	DC198

Stirrer mix; 30 min. at 125°C; severe internal fissure; closed cell

HT-17	100	HT
	25.4	TDI
	1.75	H_2O
	0.2	T-12
	0.5	33LV
	2	DC198

Stirrer mix; 30 min. at 125°C; no internal fissure; mostly closed cell

HT-18	100	HT
	25.4	TDI
	1.75	H_2O
	0.2	T-12
	0.5	33LV
	3	DC198

Stirrer mix; 30 min. at 125°C; no internal fissure; mostly closed cell

HT-19	100	HT
	25.4	TDI
	1.75	H_2O
	0.2	T-12
	0.5	33LV
	5	DC198

Stirrer mix; appeared to cream faster than HT-16 to 18; 30 min. at 125°C; no internal fissure; mostly closed cell

HT-20	200	HT
	50.8	TDI
	3.5	H_2O
	0.4	T-12
	1.0	33LV
	5	DC198

Double formulation with DC198 at 2.5 phr; stirrer mix; 30 min. at 125°C; small side fissures; mostly closed cell

HT-21	200	HT
	50.8	TDI
	3.5	H_2O
	0.5	T-12
	0.3	DABCO WT
	2.4	DC198

Stirrer mix; little rise out of oven; 30 min. at 125°C; dense foam; coarse, closed cells

HT-22	200	HT
	50.8	TDI
	3.5	H_2O
	0.5	T-12
	0.8	33LV
	0.1	DC200

Stirrer mix; 30 min. at 125°C; extremely coarse cells; appeared near collapse

HT-23	200	HT
	50.8	TDI
	3.5	H_2O
	0.25	T-12
	0.6	33LV
	1.0	DC200

Stirrer mix; 30 min. at 125°C; collapsed

<u>HT-24</u>	100	HT
	25.4	TDI
	1.75	H_2O
	0.2	T-12
	0.5	33LV
	1.0	DC1312

Stirrer mix; 30 min. at 125°C; collapsed

<u>HT-25</u>	100	HT
	25.4	TDI
	1.75	H_2O
	0.2	T-12
	0.5	33LV
	1.0	DC196

Stirrer mix; 30 min. at 125°C; coarse cells; severe internal fissure

HT-PL718 FOAMS

HT-PL718-1	70	HT
	30	PL718
	28.9	TDI
	2	H_2O
	0.2	T-12
	0.4	33LV
	1.5	DC198

Hand mix; good cream and set; 30 min. at 125°C; no fissures

HT-PL718-2	140	HT
	60	PL718
	57.8	TDI
	4	H_2O
	0.4	T-12
	0.8	33LV
	3	DC198

Hand mix; good cream and rise; 30 min. at 125°C; larger cells than HT-PL718-1; no fissures

HT-PL718-3 (same as HT-PL718-2)

Stirrer mix; good cream and rise; 30 min. at 125°C; finer cells than HT-PL718-2; internal fissures

HT-PL718-4	50	HT
	50	PL718
	29.1	TDI
	2	H_2O
	0.3	T-9
	0.2	33LV
	0.8	DC198

Hand mix; 30 min. at 125°C; poor rise; thick skin

HT-PL718-5	50	HT
	50	PL718
	29.1	TDI
	2	H_2O
	0.2	T-12
	0.4	33LV
	1.5	DC198

Hand mix; fast cream and set; 30 min. at 125°C; large internal fissure

HT-PL718-6	100	HT
	100	PL718
	58.2	TDI
	4	H_2O
	0.4	T-12
	0.8	33LV
	3.0	DC198

Stirrer mix; good cream and set; 30 min. at 125°C; internal fissure

HT-PL718-7	100	HT
	100	PL718
	58.2	TDI
	4	H_2O
	0.3	T-12
	0.8	33LV
	3.0	DC198

Stirrer mix; good cream and rise; 30 min. at 125°C; internal fissure

HT-PL718-8	100	HT
	100	PL718
	58.2	TDI
	4	H_2O
	0.2	T-12
	0.8	33LV
	3.0	DC198

Stirrer mix; good cream and rise; 30 min. at 125°C; internal fissure

HT-PL718-9	100	HT
	100	PL718
	58.2	TDI
	4	H_2O
	0.2	T-12
	1.0	33LV
	3	DC198

Stirrer mix; *good cream and rise; 30 min. at* 125°C; internal fissure

HT-PL718-10	100	HT
	100	PL718
	58.2	TDI
	4	H_2O
	0.2	T-12
	1.5	33LV
	3.0	DC198

Stirrer mix; good cream and rise; 30 min. at 125°C; internal fissure

HT-PL718-11	50	HT
	50	PL718
	26.3	TDI
	1.75	H_2O
	0.15	T-12
	0.6	33LV
	1.5	DC198

Stirrer mix; 30 min. at 125°C; internal fissure

HT-PL718-12	100	HT
	100	PL718
	52.6	TDI
	3.5	H_2O
	0.2	T-12
	0.8	33LV
	3	DC198

Stirrer mix; 30 min. at 125°C; internal fissure

HT-PL718-13	100	HT
	100	PL718
	52.6	TDI
	3.5	H_2O
	0.6	T-9
	0.5	33LV
	3	DC198

Stirrer mix; 30 min. at 125°C; internal fissure

<u>HT-PL718-14</u>

50	HT
50	PL718
26.3	TDI
1.75	H_2O
0.3	T-9
0.25	33LV
2.5	DC198

Hand mix; bad cream; improper cure with T-9

<u>HT-PL718-15</u>

50	HT
50	PL718
28.7	TDI
2	H_2O
0.15	T-12
0.5	33LV
1	DC198

Hand mix; good cream and rise; 30 min. at 125°C; small side fissure;

<u>HT-PL718-16</u>

30	HT
70	PL718
29.4	TDI
2	H_2O
0.2	T-12
0.4	33LV
1.5	DC198

Hand mix; fast cream and set; fine cells

HT-PM FOAMS

<u>HT-PM-1</u>

70	HT
30	PM20000
28.3	TDI
2	H_2O
0.2	T-12
0.5	33LV
2	

Hand mix; good cream and set; 30 min. at 125°C; small side fissure; many cell wall membranes contained small holes

<u>HT-PM-2</u>

70	HT
30	PM2000
28.3	TDI
2	H_2O
0.15	T-12
0.6	33LV
2.5	DC198

Hand mix; good cream and set; 30 min. at 125°C; internal fissure; more cell wall membrane pullback than in HT-PM-1

<u>HT-PM-3</u>

30	HT
70	PM2000
28.7	TDI
2	H_2O
0.15	T-12
0.6	33LV
2.5	DC198

Hand mix; 30 min. at 125°C; foam rise 60% of HT-PM-2; no fissures; mostly closed cell

HT-PM-4	30	HT
	70	PM2000
	28.6	TDI
	2	H_2O
	0.3	T-9
	0.2	33LV
	0.5	B3136

Hand mix; fast cream; tacky after 1.5 hrs. at 125°C; some shrinkage

HT-PM-5	30	HT
	70	PM2000
	28.6	TDI
	2	H_2O
	0.6	T-9
	0.2	33LV
	0.5	B3136

Hand mix; fast cream; 30 min at 125° ; some side fissures

HT-PL355 FOAMS

<u>HT-PL355-1</u>

90	HT
10	PL355
35	TDI
2	H_2O
0.2	T-12
0.5	33LV
1.5	DC198

Hand mix; extremely fast cream and set; 30 min. at 125°C; good rise; mostly closed cell

<u>HT-PL355-2</u>

180	HT
20	PL355
61.2	TDI
3.5	H_2O
0.3	T-12
0.75	33LV
3	DC198

Stirrer mix; extremely fast cream and rise; mostly closed cell

<u>HT-PL355-3</u>

90	HT
10	PL355
35	TDI
2	H_2O
0.2	T-12
0.5	33LV
2.0	DC198

Hand mix; fast cream and rise; 30 min. at 125°C; cells quite different from HT-PL355-1 beign much finer, less coarse; bottom blow hole; more closed cell than HT-PL355-1

<u>HT-PL355-4</u>

90	HT
10	PL355
35	TDI
2	H_2O
0.15	T-12
0.3	33LV
2.5	DC198

Hand mix ; fast cream; good rise; 30 min. at 125°C; fine, mostly closed cell

HT-PL355-5	90	HT
	10	PL355
	35	TDI
	2	H_2O
	0.08	T-12
	0.3	33LV
	2.5	DC198

Hand mix; relatively fast cream; 30 min at 125°C; good rise; blow holes; closed cell content and feel similar to HT-PL355-1

HT-PL355-6	90	HT
	10	PL355
	35	TDI
	2	H_2O
	0.2	T-9
	0.3	33LV
	2.0	DC198

Hand mix; good cream and rise; 30 min. at 125°C; very soft foam; no fissures; proper cure suspect

HT-PL355-7	90	HT
	10	PL355
	34.4	TDI
	2	H_2O
	0.4	T-9
	0.3	33LV
	2	DC198

Hand mix; good cream and rise; top tacky after 30 min. at 110°C, left for 30 additional min.; some shrinkage from walls of container; less cell wall membrane than previous formulations

HT-PL355-8	90	HT
	10	PL355
	34.4	TDI
	2	H_2O
	0.6	T-9
	0.3	33LV
	2	DC198

Hand mix; good cream and rise; top still tacky after 1 hr. at 110°C; extremely soft foam; tackiness lost overnight at room temp.; some shrinkage; no fissures; similar cell structure to HT-PL355-7

HT-PL355-9	90	HT
	10	PL355
	29.36	TDI
	1.5	H_2O
	0.4	T-9
	0.3	33LV
	2	DC198

Hand mix; good cream and rise; 1 hr. at 110°C; severe shrinkage

HT-PL355-10	90	HT
	10	PL355
	29.36	TDI
	1.5	H_2O
	0.15	T-12
	0.3	33LV
	1.5	DC198

Hand mix; good cream and rise; tack from top after 15 min. at 110°C; bottom blow hole; closed cell

HT-PL355-11	90	HT
	10	PL355
	29.36	TDI
	1.5	H_2O
	0.15	T-12
	0.30	33LV
	0.75	DC198

Hand mix; good cream and rise; some bottom shrinkage; very closed cell

HT-PL355-12	90	HT
	10	PL355
	29.36	TDI
	1.5	H_2O
	0.15	T-12
	0.8	33LV
	1.5	DC198

Hand mix; fast cream and rise; some center burn; shrinkage; very closed cell

HT-PL355-13	70	HT
	30	PL355
	42.9	TDI
	1.5	H_2O
	0.3	T-9
	0.3	33LV
	1.5	DC198

Hand mix; good cream and rise; collapsed

<u>HT-PL355-14</u>	97	HT
	3	PL355
	24.9	TDI
	1.5	H_2O
	0.5	T-9
	0.3	33LV
	1.5	DC198

Hand mix; good cream and rise; collapsed

<u>HT-PL355-15</u>	97	HT
	3	PL355
	24.7	TDI
	1.5	H_2O
	0.15	T-9
	0.3	33LV
	1.5	DC198

Hand mix; bottom shrinkage; very closed cell

HT-PL637 Foams

<u>HT-PL637-1</u>

70	HT
30	PL637
27.6	TDI
2	H_2O
0.15	T-12
0.6	33LV
2.25	DC198

Hand mix; good cream and rise; 30 min. at 125°C; stable foam; mostly closed cell

<u>HT-PL637-2</u>

70	HT
30	PL637
27.6	TDI
2	H_2O
0.15	T-12
0.6	33LV
1.5	DC198

Hand mix; good cream and ris; 30 min. at 125°C; stable foam; mostly closed cell

<u>HT-PL637-3</u>

70	HT
30	PL637
27.6	TDI
2	H_2O
0.04	T-12
0.6	33LV
2	DC198

Hand mix; good cream and rise; 1 hr. at 125°C; top tacky but tack free overnight at room temp.; stable foam; mostly closed cell

<u>HT-PL637-4</u>

70	HT
30	PL637
27.6	TDI
2	H_2O
0.4	T-9
0.6	33LV
2	DC198

Hand mix; good cream and rise; 1 hr. at 125°C; top tacky but tack free overnight at room temp.; mostly closed cell; stable foam; visually more cell wall pullback to cell ribs that T-12 catalyzed

<u>HT-PL637-5</u>	105	HT
	45	PL637
	41.1	TDI
	3	H_2O
	0.38	T-9 (0.25 phr)
	0.9	33LV
	3.0	DC198

Hand mix; tacky after 2 hr. at 110°C; shrinkage and fissures

<u>HT-PL637-6</u>	105	HT
	45	PL637
	41.1	TDI
	3	H_2O
	0.75	T-9 (0.5 phr)
	0.9	33LV
	3.0	DC198

Hand mix; slightly tacky after 2 hrs. at 110°C; small top split; mostly closed cell

<u>HT-PL637-7</u>	105	HT
	45	PL637
	41.4	TDI
	3	H_2O
	1.13	T-9 (0.75 phr)
	0.9	33LV
	3	DC198

Hand mix; tack free after 2 hrs. at 110° C; stable foam; mostly closed cell

<u>HT-PL637-8</u>	105	HT
	45	PL637
	41.1	TDI
	3	H_2O
	0.075	T-12 (0.05 phr)
	0.9	33LV
	3.0	DC198

Hand mix; tacky after 1.5 hrs. at 110°C; not good foam; visually more cell wall pullback to cell ribs than those catalyzed with higher T-12 levels

T-PL637-9	105	HT
	45	PL637
	41.4	TDI
	3	H_2O
	0.15	T-12 (0.1 phr)
	0.9	33LV
	3	DC198

Hand mix; good cream and rise; slightly tacky after 15 hrs at 110°C but tack free overnight at room temp.; mostly closed cell

HT-PL637-10	105	HT
	45	PL637
	41.4	TDI
	3	H_2O
	0.3	T-12 (0.2 phr)
	0.9	33LV
	3	DC198

Hand mix; good cream and rise; tack free after 30 min. at 110°C; mostly closed cell

HT-PL637-11	70	HT
	30	PL637
	27.6	TDI
	2	H_2O
	0.1	T-12
	0.5	33LV
	0.25	DC198

Hand mix; good cream; tacky after 30 min. at 125°C but tack free overnight at room temp.; no fissures; very coarse, closed cell

HT-PL637-12	70	HT
	30	PL637
	27.6	TDI
	2	H_2O
	0.1	T-12
	0.5	33LV
	0.5	DC198

Hand mix; good cream; tacky after 30 min. at 125°C but tack free overnight at room temp.; large internal fissure; fine, closed cell

HT-PL37-13	70	HT
	30	PL637
	27.6	TDI
	2	H_2O
	0.1	T-12
	0.5	33LV
	1.0	DC198

Hand mix; good cream and rise; rise better than either HT-PL637-11 or 12; tacky after 30 min. at 125^{o}C but tack free overnight at room temp.; fine mostly closed cell

HT-PL637-14	70	HT
	30	PL637
	27.6	TDI
	2	H_2O
	0.1	T-12
	0.5	33LV
	0.25	BF2370

Hand mix; 45 min. at 125^{o}C; slightly tacky but tack free overnight at room temp; internal fissure; coarse closed cells

HT-PL637-15	70	HT
	30	PL637
	27.6	TDI
	2	H_2O
	0.15	T-12
	0.6	33LV
	0.75	BF2370

Hand mix; good cream and rise; 30 min. at 125^{o}C; small side fissures; mostly closed cell

HT-PL637-16	70	HT
	30	PL637
	27.6	TDI
	2	H_2O
	0.1	T-12
	0.5	33LV
	0.25	B3136

Hand mix; 30 min. at 125^{o}C; coarse, closed cell

HT-PL637-17		
	70	HT
	30	PL637
	27.6	TDI
	2	H_2O
	0.15	T-12
	0.6	33LV
	0.75	B3136

Hand mix; 30 min. at 125°C; good cream and rise; very small side fissures; fine, mostly closed cell

HT-PL637-18		
	70	HT
	30	PL637
	27.6	TDI
	2	H_2O
	0.1	T-12
	0.5	33LV
	0.25	DC190

Hand mix; relatively poor rise; 1 hr. at 125°C; coarse, closed cell

HT-PL637-19		
	70	HT
	30	PL637
	27.6	TDI
	2	H_2O
	0.1	T-12
	0.5	33LV
	0.25	DC196

Hand mix; good cream; 1 hr. at 125°C; some gas release before set; extremely coarse, mostly closed cell

HT-PL637-20		
	105	HT
	45	PL637
	41.4	TDI
	3	H_2O
	0.23	T-12
	0.9	33LV
	0.75	DC198 (0.5 phr)

Hand mix; 30 min. at 110°C; relatively poor rise; some shrinkage; side fissures; coarse, closed cell

HT-PL637-21	70	HT
	30	PL637
	27.6	TDI
	2	H_2O
	0.15	T-12
	0.6	33LV
	0.75	DC198

Hand mix; good cream; 30 min. at 125°C; small side fissures; closed cell

HT-PL637-22	105	HT
	45	PL637
	41.1	TDI
	3	H_2O
	0.23	T-12
	0.9	33LV
	1.5	DC198 (1 phr)

Hand mix; good cream and rise; finer cells than HT-PL637-18; mostly closed cell

HT-PL637-23	105	HT
	45	PL637
	41.1	TDI
	3	H_2O
	0.23	T-12
	0.9	33LV
	2.25	DC198(1.5 phr)

Hand mix; good cream and rise; 30 min. at 110°C; mostly closed cell

HT-PL637-24	105	HT
	45	PL637
	41.1	TDI
	3	H_2O
	0.23	T-12
	0.9	33LV
	3	DC198(2 phr)

Hand mix; good cream and rise; 30 min. at 110°C; mostly closed cell

HT-PL637-25	105	HT
	45	PL637
	41.1	TDI
	3	H_2O
	0.23	T-12
	0.9	33LV
	3.75	DC198 (2.5 phr)

Hand mix; good cream and rise; 30 min. at 110°C

HT-PL637-26	140	HT
	60	PL637
	39.6	TDI
	2.5	H_2O (1.25 phr)
	0.3	T-12
	1.2	33LV
	4.0	DC198

Hand mix; good cream and rise; 30 min. at 110°C; no fissures; mostly closed cell

HT-PL637-27	140	HT
	60	PL637
	44.7	TDI
	3	H_2O (1.5 phr)
	0.3	T-12
	1.2	33LV
	4.0	DC198

Hand mix; good cream and rise; 30 min. at 110°C; no fissures; mostly closed cell

HT-PL637-28	140	HT
	60	PL637
	49.7	TDI
	3.5	H_2O (1.75 phr)
	0.3	T-12
	1.2	33LV
	4.0	DC198

Hand mix; good cream and rise; 30 min. at 110°C; no fissures; mostly closed cell

HT-PL637-29	50	HT
	50	PL637
	27.2	TDI
	2	H_2O
	0.15	T-12
	0.5	33LV
	1.0	DC198

Hand mix; 30 min. at 110°C; no fissures; mostly closed cell

CHEMICAL GLOSSARY

RESINS

HT	Polybutadiene Polyol (R45HT, ARCO Chemical)
PL355	Pluracol 355 - Amine based poly(oxypropylene) polyol (BASF Wyandotte Chemical Company)
PM	Polymeg 2000 - poly(oxytetramethylene) glycol (Quaker Oaks Company)
PL718	Pluracol 718 - poly(oxypropylene) triol (BASF Wyandotte Chemical Company)

SURFACTANTS

DC198	Silicone Surfactant (Dow Corning)
DC200	Silicone Fluid (Dow Corning)
DC1312	Silicone Surfactant (Dow Corning)
DC196	Silicone Surfactant (Dow Corning)
B3136	Silicone Surfactant (Th. Goldschmidt Products Corp.)
DC190	Silicone Surfactant (Dow Corning)
BF2370	Silicone Surfactant (Th. Goldschmidt Products Corp.)

AMINE CATALYSTS

DABCO 33LV	A 33.3% solution of triethylenediamine in dipropylene glycol (Air Products)
DABCO WT	Amine Catalyst (Air Products)

TIN CATALYSTS

T-9	Stannous Octoate (M&T Chemicals)
T-12	Dibutyltin dilaurate (M&T Chemicals)

ISOCYANATE

TDI	80/20 mixture of 2,4 toluenediisocyanate to 2,6 - toluenediisocyanate (Dow Chemical)

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